ZOÖLOGY

DESCRIPTIVE AND PRACTICAL

BY

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Part II

PRACTICAL

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"If you study Nature indoors, when you go outdoors you cannot find her." — *Agassiz.*

"He is a good naturalist who knows his own parish thoroughly." — *Kingsley.*

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PREFACE.

THE principal change from the earlier edition consists in the addition of directions for field study and for the laboratory study of the live animals. In the nature of the work these directions must be somewhat general, and should be modified by the teacher to suit local conditions and the requirements of the class. Because of the fact that conditions greatly vary in different localities, it is not to be supposed that each teacher can accomplish all the work here outlined. It is hoped that there is variety enough to suit most localities. Other types may often serve the purpose better than these here presented. The work must also be adapted to the age and experience of the students and to the time allotted to the subject. The author's reasons for the order of study here presented are given in the preface of the descriptive part of the book.

For convenience, the practical part follows the descriptive text, but, of course, the actual study of the types should precede any assigned lesson or reading in reference books.

The "Suggestions to the Student" have been entirely re-written.

The "Suggestions to the Teacher" have become so extended that they are no longer included in the book, but are printed in a separate pamphlet, which can be obtained of the publishers. In this pamphlet are hints as to laboratory equipment, class-room management, notes and drawings, supervision of dissection, collecting outfit, field work, preservation of material, etc.

A full-page cut of the microscope has been introduced to accompany the directions for its manipulation. The author takes this occasion to thank the firm of Bausch and Lomb for

their kindness in furnishing the electro for this cut. A few other cuts are added to illustrate the work of dissecting.

The importance of the actual study of types cannot be too strongly urged. Without some real knowledge derived from his own observation, the student has no foundation on which to build the structure of information that he gets from reading and from lectures. To a few fixed facts of experience he can firmly fasten that which he acquires through the experience of others, but which would otherwise be vague and fleeting.

The earlier edition of the author's "Practical Zoölogy" was corrected by the late Professor Alpheus Hyatt of the Boston Society of Natural History; President David Starr Jordan of Leland Stanford, Jr., University; Professor N. S. Shaler, Harvard University; Professor H. Garman, State College of Kentucky; Mr. B. H. Van Vleck; Mr. J. Y. Bergen, Jr., of the English High School, Boston; Professor R. E. Call; Mr. E. P. Jackson, Boston Latin School; and Professor L. M. Underwood, Columbia University.

The proofs of this edition have been critically read by Professors M. F. Arey, State Normal School, Cedar Falls, Ia.; A. C. Boyden, State Normal School, Bridgewater, Mass.; M. J. Elrod, University of Montana; J. W. Folsom, University of Illinois; H. Garman, State College of Kentucky; W. S. Jackman, University of Chicago; H. S. Jennings, University of Michigan; J. M. Johnson, Peter Cooper High School, New York; S. J. Hunter, University of Kansas; Louis Murbach, Detroit High School; Frank Smith, University of Illinois; H. B. Ward, University of Nebraska.

The directions for the study of the honey-bee were written by Mr. Charles H. Allen, Bloomington, Ill., High School.

To these gentlemen the author is deeply indebted, and offers them his most sincere thanks.

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INTRODUCTION.

TO THE STUDENT.

Class-room Notes. — You should make careful notes of all your observations and work, both in the class room and the field. The temporary notes may be written with a pencil in any convenient notebook. The following plan, however, is recommended. Get a pad of unruled paper, about six inches long and four inches wide. On this, the notes and temporary drawings are to be made, using only one side of the paper. Remove the sheets as they are filled. Keep them in a strong manilla paper envelope, half an inch wider and an inch shorter than the sheets. Label the envelope "Zoölogy"; or, better, have a number of envelopes labeled with any convenient subdivisions of the subject. As much or as little of the notes as desired may be carried. These envelopes can be carried in the pocket, and the notes are available at short notice, and can be consulted many times where a notebook, with all the notes of a term, would not be at hand. A still further advantage is that any notes or drawings on the same subject, made later, can be inserted at the right place, which could not well be done with a regular bound notebook. As the notes accumulate those not in immediate use may be stored in larger envelopes and kept as best suits your convenience. A part of the "pad" of note paper should be carried to all class-room exercises, whether it be a laboratory exercise or a recitation, to take any needed notes. Record should be made of all animals studied, whether those given to students for detailed examination or dissection, or the exhibition specimens brought in from day to day. Many statements made by teacher

or fellow-pupil are worth copying in the notes. Notes should also be made of your reading about the animals that are brought in.

Field Notes. — For field notes a well-bound notebook is usually better. It should be leather-covered and smaller than the class-room note paper. In this book you should make record of your outdoor observations. In the directions for "Field Study" are many questions for you to answer. It is to be hoped that you will ask many other questions and record your answers. If you can give no immediate answer, do not give it up. Keep on looking and keep on thinking. Your "field notes," "outdoor study," "Saturday book," or whatever you choose to call it, should be your constant companion. If the book has not a loop to hold a pencil, see to it that you have two or three short stubs of pencil in your pockets.

Equipment for Field Work. — Suggestions will be found in connection with the field study of insects, birds, etc. But the student should always carry a convenient lens, for there are many specimens which ought to be examined when found. Almost any small, compact lens of moderate power will be sufficient, such as the linen-tester, which folds into very small space, the lenses in hard rubber or metal cases, etc. The tripod lens is rather inconvenient to carry in the field, but better than many others for class-room work. When possible carry a field glass. It will enable you to bring close to you many birds and other animals that will not allow you to come close to them. Even if your excursion is for insects, or other specimens which you can easily approach, you do not know what opportunities you may have to see distant specimens. The modern field glasses, with prisms instead of lenses, are superior to those of the old style, and in addition are very light, hardly weighing more than ordinary opera glasses. They are, however, rather expensive. Common opera glasses serve very well for all the ordinary purposes of studying birds.

Permanent Notes. — The permanent notes should be written with ink on ruled paper ten inches long by eight inches wide.

The paper should be ruled on both sides, with ruled marginal spaces, an inch on one edge and an inch and a half on the other; the wider margin should be perforated for binding. For the drawings, good, unruled paper with the same marginal lines and perforations should be used. Pads of these two kinds of paper, with labeled covers, are furnished by school-supply dealers. This system allows any desired arrangement of the notes and drawings, irrespective of the time when they were made. They may also be put together temporarily in any way desired. When you hand in to your teacher any detached papers, write your name and the date on the perforated margin, where it will not mar the completed notes. On the cover should appear the subject, your name, the name of the school, and the date. Brief marginal headings are often helpful, to yourself as well as to your teacher. The permanent notes are usually to be derived from the temporary notes "revised and enlarged." They should be in your own words, and your very best language should be used. The notes should be not only accurate, but they should be interesting. Avoid long-drawn sentences. Brevity is the soul of wisdom as well as of wit.

Drawings. — These should first be made in pencil. Have a medium hard pencil and keep it sharp. Avoid shading, but make outline drawings. Make the first lines faint, and then, if they suit you, that is if they conform to the thing itself, go over them again and make them heavier. Make no line or mark that does not correspond to something you see in your specimen. Proceed slowly, and whenever you are dissatisfied erase the line, using the kneaded rubber eraser. Do not abandon the drawing to begin another; keep "doctoring" the drawing with which you start. Often it is desirable to make some feature more distinct than it appears in the specimen itself. For instance, in representing the back of a bug or a beetle, the mode of overlapping of the wings is the important fact to be brought out. But the line of union or of overlapping may be decidedly indistinct, whereas some ridge that is of no significance may be

prominent. Bring out the important features; often ignore features that are of no significance. Drawing should show structure rather than mere appearance. Represent things not so much as they appear, but rather as they really are. To make the suggestions more definite, suppose you are to make a drawing of the perch. Prop the fish up so you get a square view of its left side. In the first place the drawing should be of good size, so there will be room to put in details without having them crowded. About eight inches will be a good size to place lengthwise on the drawing paper. It is better to make the original drawing of the same size you wish for the finished drawing. Determine the place of the drawing on the sheet, leaving about equal space at each end, and with the drawing a little above the middle, as the general label should always be beneath the drawing. First draw a straight line for the longitudinal axis. Next determine where the greatest depth of the fish is, and draw a line, the transverse axis, at right angles to the main axis. Note carefully whether or not the transverse axis is divided into two equal parts by the longitudinal axis, *i.e.* whether the body of the fish is more above or more below the main axis. Having these points located, proceed to draw the outlines of the fish, watching closely to see that you get the right proportions. Go no faster than you can give satisfaction to your own criticism. After completing the general outline, draw the lateral line. Then make a dot for the hindmost tip of the gill cover, which marks the posterior end of the head. Proceed to put in the details of the head, the parts of the gill cover, the mouth, the eye, etc. In drawing the mouth, show it as it is and be careful not to be guided by any preconceived notions of it. Block out and then fill in the different fins. Unless you have an abundance of time, do not attempt to represent the scales, and it is not essential to show the colors.

When the above features are satisfactory to you as drawn in pencil, proceed to trace over the lines with ink. This is not so easy, as you cannot readily erase. Have confidence in the

steadiness of your hand and you will probably get along all right. Use a good, black drawing ink, and a clean, fine-pointed pen. Trace from left to right, drawing the pen slanting well back so it will slide easily. Work always on the "out curve," — *i.e.* supposing the drawing is right side up, begin at the head and trace the outline of the back; when you have reached the tail, turn the drawing upside down, and trace the ventral margin, beginning with the tail end. By this method you will always be making an easy curve, with the elbow as the center of the curve. Follow this plan wherever there is a curved line, always turning the drawing so that the concave side of the curve is toward you. Try to give an even, steady motion. Whenever possible avoid going over the line a second time with the pen. If necessary to trace over, or especially if you stop to re-ink, begin a little back of where you stopped, in order to make the line smooth and even. If you attempt to trace by pushing the pen, or even by drawing it sidewise, it may occasionally "stick and sputter"; drawing the pen lengthwise, as above suggested, seldom makes any such trouble.

Now comes the labeling. Place the label on each part, or very close to it. Never letter, or number, the parts, with explanations below. This method is wasteful of time and eyesight. Plan the labeling carefully before you begin. Do not make the labels crowded in one part and scattered in another if you can distribute them more evenly. Avoid drawing a dotted line across one organ to the one designated. Organs near the margin may well be labeled outside, using dotted lines if necessary. Organs far from the outside are best labeled on the organ itself in the most available place. Print all labels, using the gothic type, that is, without crosses at the ends of the lines. To insure uniformity in the letters make parallel guide lines with the pencil; then letter with pencil; after tracing the letters with ink, erase the guide lines. The general label, below, should be larger than the detail labels. See the cut of the perch as an example of labeling.

If water-color drawings are to be made, first draw the outlines in black ink. After this is dry, paint in the water color. Do not use colored pencil crayons. Only solid organs, such as the liver, should be represented in solid color. Hollow organs, such as the digestive tube, should be represented in outline to show that they are open. The following colors may be taken to represent the different systems: arteries, red; veins, blue; digestive tube, brown; liver, green; kidneys, purple; lungs, pink; nervous system, gray; reproductive glands, orange.

Do not be discouraged if your first drawings do not satisfy you. Drawing requires time and patience. Without these even the most gifted artist produces nothing worthy. The majority of students say at first, "I can't draw." After some suggestions, and a little practice, almost every one can show creditable results. The first thing is to *see clearly*. See each line in the specimen, and make each mark in your mind, before you put it on paper. In such simple drawings as are here required, failure to draw well, after a little experience, usually indicates failure to see well. It is more head work than hand work. Perhaps the best definition of drawing is that given by the little girl who said "drawing is thinking, and then marking around the think."

Dissecting. — The instruments needed are: a pair of scissors, a pair of forceps with roughened tips that will hold objects securely, a scalpel, a cartilage knife, a blowpipe, two dissecting needles, and a lens. The needles may be made by thrusting the eye end of a strong needle into a wooden handle. These instruments are usually sold in sets in a convenient carrying case; the cloth-lined leatherette cases are more compact than the wooden boxes. The cutting instruments should be kept sharp, for which a small oilstone is desirable. Often the reason why scissors do not cut is because they are loose at the joint. They should sharply snip a hair, or thin paper, at the very tip of the blades. Avoid straining the scissors by trying to cut tough or hard objects near the tip; cut such things near the joint. Use the cartilage knife for the rougher work, where you are likely to

strike bone; keep the scalpel for the finer work. Be careful to keep the joint of the scissors dry. Do not get blood in it while dissecting, nor water when cleaning. If the joint is kept well oiled, watery liquids are usually kept out. Always clean the instruments after dissecting, using no more water than is needed; often a moist cloth will be sufficient. See that they are dry before you put them away. If they are to remain unused for some time, rub them with an oiled rag, or slightly smear them with vaseline.

The scissors should be used much more than the beginner would suppose. All small objects and especially thin membranes are better cut with the scissors than with the scalpel, for the reason that each blade of the scissors holds the object for the other blade, whereas the knife tends to push out of the way the object to be cut, and often leads to the cutting of underlying tissues that should be left uninjured. While cutting with one hand, whether with scalpel or scissors, always use the forceps in the other hand to steady the object, and especially to hold the edge while cutting any thin membrane. This is especially necessary when cutting through the wall into any cavity. Hold the forceps as you would a pen, and not as a pair of tongs. Delicacy and not strength is required. By holding the forceps as you would a pen, you keep the wrist down in a restful position, and can often let it rest on the edge of the dissecting pan; your hand is thus less likely to be in your light. Do not touch objects with a blade of a cutting instrument unless you intend to cut them. If you wish to push an organ aside, or turn it over, use the fingers, forceps, or the handle of the scalpel. In much of the dissecting the handle of the scalpel should be used, chisel-fashion, scraping and pushing, rather than cutting. In fact, the handle of the scalpel should be used more than the blade. Many tissues are tough and will stand dragging or tearing, whereas a slight cut will cause bleeding enough to interfere seriously with the work, not only making the work unsightly, but obscuring the view. This is especially

true of such delicate tissues as that of the liver. The blowpipe should be used to inflate thin-walled tubes and cavities. It is also useful as a probe. A piece of copper wire, or an aluminum hairpin straightened out and tipped with sealing wax, serves well as a probe. For tracing very slender ducts use a bristle tipped with a very small drop of sealing wax. When dissecting specimens under water do not lift the specimen out to see anything. The soft tissues sink down together in a mass that prevents seeing as well as before, whereas while under water they are partly floated up and thus made more distinct. It may be necessary, however, occasionally to lift the specimen from the water to make a cut near the ends, or to make some new adjustment, as inflating through the mouth. Always follow directions closely when dissecting. By not doing so you are likely to waste both time and material. Read the whole sentence before making a new cut. It is a good rule not to cut anything unless you know what it is. Keep your thinker just ahead of your cutter. If in doubt, ask help of your teacher.

General Suggestions. — Arrange your table, and your position, so as to get enough, but not too much, light. If two work together, be careful not to let the heads or hands shut out needed light. At the beginning of the term learn the rules regulating the laboratory, and carefully observe them. But whatever the rules, be sure and keep your own table neat and clean. If other students use the same table, put away all your belongings. If you have the exclusive use of it, keep books, instruments, etc., in order. Take pride in making your notes and drawings the best possible. The book is yours to keep, and, if well done, will likely be useful to you later. It is a worthy ambition to desire to excel. In all your work, *think* about what you are doing. Do not let yourself drift along thoughtlessly. No work succeeds without live interest in it, and thoughtful attention. Try to think out the use of each part or organ, the ways in which the animal is adapted to its place of living and to all its surroundings. This habit of thinking about the things you are

working over will fill them with an interesting meaning, and the work will cease to be drudgery and become a source of increasing entertainment.

Books of Reference.

1. The American Natural History, Hornaday.
2. Riverside Natural History, Kingsley.
3. A Manual for the Study of Insects, Comstock.
4. Key to the Birds of North America, Coues.
5. Manual of the Vertebrates, Jordan.
6. A Naturalist's Rambles about Home, Abbott.
7. Animal Life, Jordan and Kellogg.

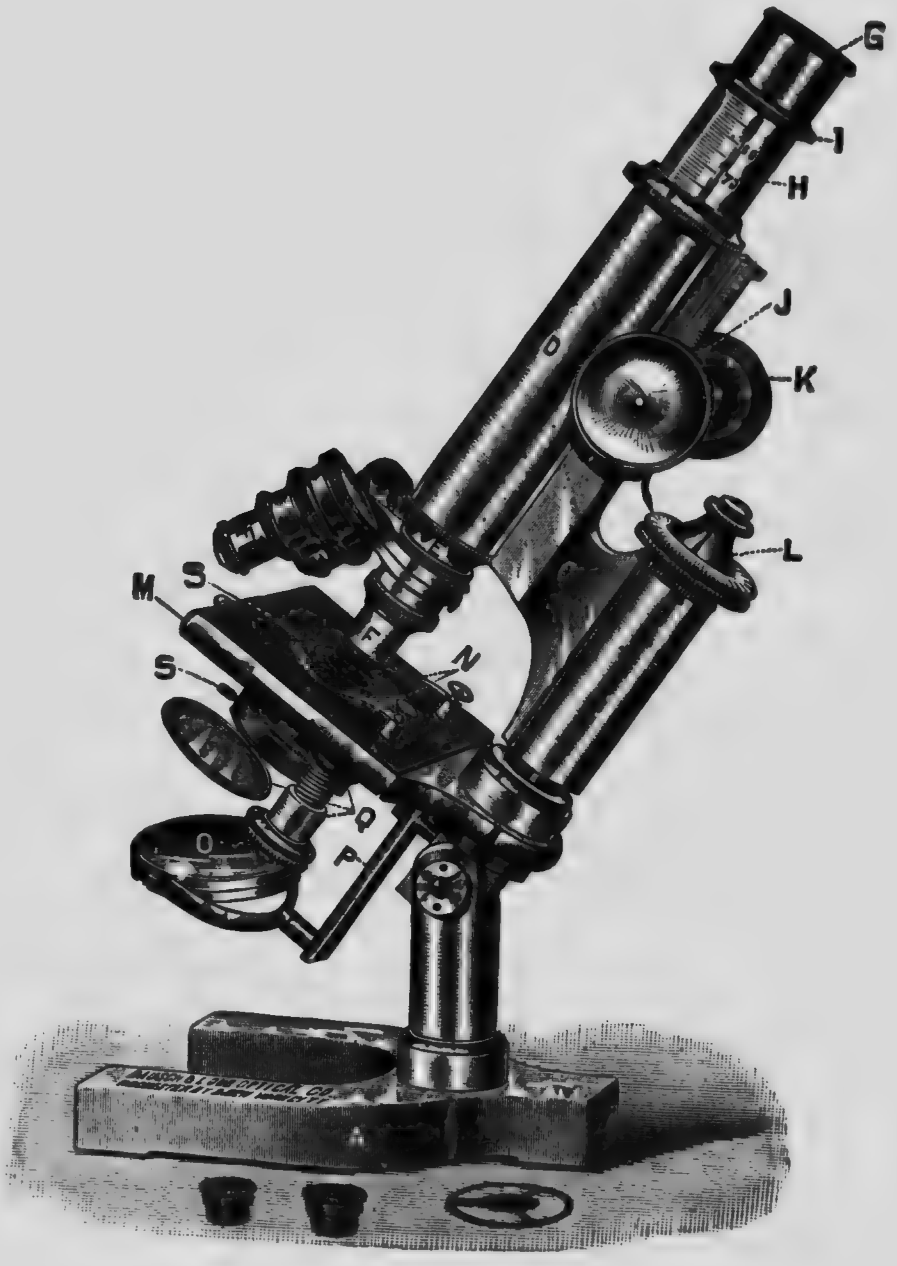
The first five of these should be used for reference. **Each student ought to read the last two.**

USE OF THE MICROSCOPE.

General Rules. — 1. Do not touch lenses, nor allow them to touch anything. 2. Keep the instrument away from dust. 3. If dust gets on a lens blow off as much as you can and then wipe with chamois skin, or clean soft cloth, such as old linen. Handle the microscope by the pillar below the stage.

Setting up a Microscope. — The eyepiece should slip easily into place by its own weight. To attach an objective, first run the tube up by the coarse adjustment, till the lower end of the tube is two or three inches from the stage. Then hold the objective with the thumb and finger of one hand while the other hand screws it to place. See that the threads catch fairly; do not use force or you may ruin the threads. Take care not to touch the lens.

Use of a Low-power Objective. — Place on the stage a slide holding a mounted preparation. Slip the ends of the slide under the clips. Place the specimen over the center of the hole in the stage. Turn the mirror so that it throws light through the hole upon the mounted object. Lower your head to the level of the stage and watch while running the tube down by the coarse adjustment; stop when the objective is a quarter of an inch from the glass slide. Take hold of the milled head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of the coarse adjustment; look through the eyepiece and slowly raise the tube until you see the object distinctly. Move the slide till the object, or the part you wish to examine, is in the center of the field of view. Now use the fine adjustment. Never turn the milled head of the fine adjustment more than two or three turns in either direction.

Use of a High-power Objective. — Begin as with the use of a low-power objective. Lower the tube until the objective almost touches the cover glass, watching closely with your head down on a level with the stage. Look through the eyepiece; by means of the coarse adjustment, slowly raise the tube till the object comes into view. Then use the fine adjustment till the outlines become sharp and distinct. Be very careful not to run the objective against the cover glass. If you do this, you may ruin the preparation and injure the lens.

The Diaphragm. — Use an opening in the diaphragm of about the same size as the front lens of the objective.

Use of the Eyes. — Always keep both eyes open when using a microscope. This may be a little confusing at first, but you will soon learn to ignore what the other eye sees.

Read "Practical Methods in Microscopy," Clark (D. C. Heath & Co.).

Parts of a Microscope.

A. Base.
B. Pillar.
C. Arm.
D. Body.
E. Nose piece.
F. Objective.
G. Eyepiece.
H. Draw tube.
I. Collar.
J. Coarse adjustment.
K. Milled head of coarse adjustment.
L. Micrometer screw of fine adjustment.
M. Stage.
N. Clips.
O. Mirror.
P. Mirror bar.
Q. Substage.
S. Diaphragm.

$$2F_2 + 3H_2O \rightarrow Fe_2O_3 + 3H_2$$

ZOÖLOGY: DESCRIPTIVE AND PRACTICAL.

PART II. PRACTICAL.

CHAPTER I.

COLLECTING INSECTS.

Apparatus. — 1. *Killing Bottle.* Get a wide-mouthed bottle, two or three inches wide and five or six inches high, with a good, sound cork which fits well; half a pint of plaster of Paris; and a lump of cyanide of potassium, about an inch square and half an inch thick, though the equivalent of this in smaller pieces serves as well or even better. In handling the cyanide of potassium great care must be observed, for it is a violent poison; not only is it a stomach poison and a blood poison, but even its fumes are poisonous. It is much safer to handle it with forceps, or, if these are not at hand, pick it up with a piece of paper. Lay the pieces of cyanide of potassium in the bottom of the bottle, and pour in just enough water to cover them; then sift in plaster of Paris till the water is all taken up. The bottle should be left uncorked for a few hours; during this time it should be set away where it can harm no one, for the poisonous fumes will escape. If any loose plaster of Paris remains, empty it out; cork the bottle tightly. It should be labeled "poison" and kept out of reach of children. Such a bottle is usually called a "cyanide bottle."

Insects may also be killed by chloroform, by putting a few drops into a bottle with the insect. This method is desirable for

moths and butterflies, which often become damaged in a cyanide bottle. A drop or two of gasoline placed on the thorax and abdomen of an insect will usually kill it quickly and not injure it. Hard-bodied insects, such as beetles, may be dropped at once into weak alcohol; but this would not do for delicate insects, such as butterflies.

Many insects may be captured directly in the bottle; especially is this convenient when insects are found on leaves and flowers. Bring the bottle up under the insect with one hand; with the cork in the other hand quickly push the insect into the bottle. This is very desirable in capturing bees or other stinging insects, ill-smelling bugs, blister beetles, etc.

2. *Insect Net.* Get a light wooden handle about three feet long, and the same length of No. 8 brass wire. Bend the wire into a circle about ten inches in diameter, cross the ends, and bend them so that after crossing they will extend alongside the handle. Bend each end at a right angle, so it may be driven into the handle to keep it from slipping off. Cut a notch in the end of the handle, fit the ring to it, and bind it on firmly with fine wire. The common error is to get too long and heavy a handle. A light, quick swing will secure more insects than a long reach. A piece of cane pole would be excellent if a ferrule were made to fit over the end; otherwise it would be likely to split. The bag should be of cheese cloth or Swiss, about eighteen inches deep and rounded at the bottom. The net is likely to become frayed out along the ring, from striking over bushes; hence it is best to sew a strip of strong muslin along the ring, and then sew the bag to this strip. When a flying insect, such as a butterfly, is caught, the net should be thrown over to one side by a quick turn of the wrist, so the insect cannot escape. Often the collector is more successful if, instead of running down a butterfly, he watches it till it lights, and then quietly claps the net over it. After the insect is caught in the net, the bottle, uncorked, may be pushed into the net and around the insect, or the insect pushed into the bottle by means of the cork. Many specimens may be obtained

by sweeping the net along over the top of the grass and over the tops of bushes, even where no insects are seen.

3. *Boxes.* The collector should also carry an extra bottle or a box or two, into which insects may be put after they have been killed. This makes room for new insects in the cyanide bottle, and keeps them better, as the newly introduced specimens sometimes struggle and may injure other specimens. Baking-powder cans and cocoa boxes are very convenient. A shallow cigar box is good for butterflies, as they may be pinned to the bottom so they will not slip about and be injured.

4. *Shell Bag.* For carrying the above apparatus, the most convenient thing is what is known as a shell bag. It is of strong canvas, and provided with a good shoulder strap. Ordinary pockets do not serve well for all the needed material. While the net is in use, the bottle and the boxes may all be safely held in the bag and out of the way of the arms and hands. The common "schoolbook bag" may be used, but they are often very weak, and likely to give way when one is forcing his way through weeds and bushes, and may be lost without being noticed. A good shell bag will last almost a lifetime for this work.

General Suggestions on Collecting. — For most insects the best time is in the middle part of a bright, warm day, for insects are most active in warm weather. But one should not neglect collecting on dark or cold days. At such times one may learn where insects hide. Not only the places where insects hide, but their colors and positions should be carefully noted, as these help to conceal them. Turn over boards, stones, and pieces of bark; pry off pieces of loose bark from logs and stumps; kick to pieces rotten stumps; and look into the crevices in fences, and about porches, etc., for insects in hiding. Careful work will secure many specimens on days when almost no insects are seen moving, and when the casual observer would say that there are none to be found. Butterflies are well kept in a fold of paper as follows: Take a piece of paper two inches longer than wide; three and a half by five and a half inches is large enough for most specimens.

Fold the paper diagonally, with about an inch of each end projecting; drop the butterfly in, and fold the edges over to keep it from slipping out. This may safely be carried in a box, a pocketbook, notebook, or inside the sweat band of the hat. If one catches an insect, with no other way of carrying it, it may be pinned into the crown of the hat on the inside; here is room for it, and no one will be likely to notice the projecting tip of the pin. An umbrella may be very useful in collecting. Hold the umbrella spread and inverted under the branches of shrubs and trees, and beat the branches with a stick, or jerk them with the handle, if it has a hook.

Collecting by Artificial Light. — A lamp at a window, as when studying, often brings valuable specimens. Electric lights along the streets draw swarms of insects. It will pay the collector to visit a number of lamps during the evening. Early in the morning one may find some specimens, though many will have flown or crawled away, and some may have been ruined by being trampled upon.

Sugaring. — Many moths fly only at night. A favorite method of capturing these is to make a thick sirup of brown sugar; daub this on the bark of trees, then visit these places to catch the moths feeding on the sweet bait. The collector sets a series of these baits, as a trapper sets a "line" of traps, and visits them in series. A lantern should be carried; the ordinary lantern serves about as well as a dark lantern. Sometimes the bottle can be put over the moth before it attempts to escape. In this way some of the finest night moths are taken, and of kinds that are rarely seen in the daytime.

Breeding Cages. — All the foregoing modes of capture are likely to injure the specimens. The surest way to get perfect specimens is to rear them. For this one may gather the cocoons and keep them till the insects emerge. Better still, get the larvæ, keep them and supply them with food till they spin their cocoons, or go into the pupa stage; then one can be sure he knows the

kind of larva from which any given adult comes. There are many adult insects whose larval stage is unknown, or little understood.

When a caterpillar or other larva is taken, the collector should note on what it is feeding, and it should be supplied with the same, or very similar, food, as long as it continues to eat. If the larva is not on any plant, but is crawling over a walk or on a fence, it may be because it was shaken off the plant on which it was feeding; very often, however, the larva, when thus found, has done eating and is seeking a convenient place to go into the pupa stage. If so, it will not need food. It is safe to offer food in any case.

Larvæ should be kept in roomy cages. And, since many larvæ go into the soil to pass their pupa stage, it is best to provide soil for any larva whose habits are not known. A convenient breeding cage may be made of a starch box by sawing off about one third of the length of the wooden cover and sliding it into the farthest end of the top. Then set the box on end, with this covered part down, and fill with soil as far as the wooden cover extends. Cut a glass cover to slide in and fill the rest of the opening; make a hole for ventilation and cover it with wire screen. If a larva that does not pupate underground is reared in such a box, no harm will result. It is well to have several such boxes in readiness for the work. A jelly tumbler serves very well as a breeding cage for small insects. A lamp chimney may be used as a breeding cage; tie netting over the top.

PRESERVATION OF INSECTS.

Pinning. — Most insects are mounted upon a pin passed through the center of the thorax. One third of the pin should project above the back. Beetles are usually pinned through the right wing cover, at such distance from the base of the wing that the pin emerges between the second and third pairs of legs. It is better to get regular insect pins, which are to be obtained from dealers in naturalists' supplies. Common pins may be used, but they are likely to rust. Medium-sized insect pins are best for

most specimens (No. 4, Kläger), though, if an extensive collection is to be made, there should be an assortment of pins.

Labeling. — The name of the insect, with date and locality, should be on a small label, on the pin about halfway between the insect and the bottom of the box. The name of the order or family should be at the beginning of the group, whether this occupies a whole box or less.

Boxes. — For ordinary small collections, the common cigar boxes are very convenient. Pupils can usually get them for nothing. The bottom should be lined with sheet cork, or thin slices of common corks can be fastened in at the place where the insects are to be pinned. It is best to devote a box to each order of insects, or even to families where many insects are collected. The boxes should be labeled on the outside near one end, so that they may be set on end on a shelf, and the label will show like the title on the back of a book. A set of shelves should be made of the right hight to accommodate the boxes as thus set on end.

Spreading Insects. — Beetles, bugs, flies, etc., are usually mounted with the wings folded. But the wings of moths, butterflies, dragon flies, etc., should be spread. And it is well to mount some locusts, beetles, bugs, etc., with the wings spread, for the sake of comparison.

Spreading Boards. — For spreading the wings of insects, a spreading board or setting board is used. This consists of two strips of soft board, fastened to a base, with a groove between them for the body of the insect, while the wings rest on the two side strips. At the bottom of the groove there should be a strip of cork to receive the pin. Place the insect in the groove, pinned firmly to the cork. Then insert a pin into the wing, back of the large veins, near the anterior border, and draw the wings forward until the hinder borders of the two hind wings are in a straight line. First fasten the wings in this position with narrow strips of paper held by pins. Then place a larger piece of paper over the wings and pin firmly. Sometimes strips of mica are used instead

of paper. Sometimes strips of glass are used, the weight being enough to hold the wings in place.

Relaxing Insects. — If insects become dry before they are spread there is danger of breaking them. They need softening. This is done by placing them in a moist place. They may be placed on dry paper over wet sand; or put wet paper into a jar, lay dry paper over this, and place the insects on the dry paper and cap the jar tightly. In a day or two they will be relaxed so they may be safely handled. A few drops of carbolic acid will retard the growth of mold.

Mounting Microscopic Insects. — Minute insects, such as fleas, or small parts of insects, such as an eye, leg, sting of a bee, etc., can readily be mounted and permanently preserved, ready for examination at any time. Such material should first be placed in alcohol. If it is soft material it should first be put into fifty per cent alcohol, in which it should not remain more than half a day; then it should be transferred to seventy-five per cent alcohol for twenty-four hours, and then kept in strong (ninety-five per cent) alcohol till ready for mounting. Pour a small quantity of oil of cloves into a watch glass and place the object to be mounted in it; this is to remove the alcohol and make it clear. Then lay it on the center of a slide in the desired position, cover it with a drop of Canada balsam, and lay a clean cover glass on it. Keep it on a level surface, so the cover glass will not slip, for a few days till the balsam has hardened. Label it at one end of the slide and keep in a suitable tray.

GENERAL PLAN FOR FIELD STUDY OF INSECTS.

Insects vary so greatly that no one plan of study will serve well for all. But the following scheme will serve in a general way for the main line of work, which must be varied to suit special cases.

Find out by direct and continuous observations in the field: —

1. Where does the insect live? On the ground? In water? On plants? If the latter, does it stay mostly on the stem or on the leaves?

2. What is its fitness for its place of living?

a. In locomotion. Does it swim, creep, walk, jump, or fly? Or has it more than one of these modes of locomotion? How is it fitted for moving?

b. General form. Is it slender or stout? Rough or smooth? Does it fold the wings when at rest, or keep them extended? Why?

c. Color. How is its color related to that of its surroundings? Would some other color be as suitable for it?

3. What does it eat? What kind of mouth parts has it, and how are they adapted for the food? Does it eat little or much? Does it store food, or depend on foraging daily?

4. Does the insect grow? If so, is the growth like that of other animals?

5. What enemies has this insect? How does it escape or avoid them?

6. Has this insect a home? Or any regular place to which it resorts? Where does it stay at night? In rough weather? Does it work by day or at night?

7. Does it lead a solitary life? Or is it social? If social, to what extent is there division of labor in the community?

8. How many kinds of insects in the community? How do the sexes differ in appearance, structure, and habits?

9. Do they live over winter? What provision is there for the continuation of the species? How long does an individual live? Are the different forms equally long-lived?

10. What are the stages of its development? Is there a metamorphosis, or merely an increase in size? How long is it in reaching maturity?

11. What senses does it use in its daily round? Are these well developed? Has it a sense of direction? Does it ever get lost?

12. If it visits plants, does it show preference for any particular plant? Does it visit many kinds of plants? What does it get from the plant? Does it do the plant any harm? Does it do the plant any good?

13. Can it display any colors that are ordinarily concealed? If so, why is this? How are such colors concealed?

14. Does this insect resemble any insect of another group? If there is resemblance, is it of any advantage?

15. How do insects compare with other animals in strength?

CHAPTER II.

INSECTA.

THE GRASSHOPPER.

The Parts of the Body.

(1) The foremost, or **anterior**, part is the **head**. (2) The middle part is the **thorax**. (3) The hinder, or **posterior**, ringed part is the **abdomen**.

THE HEAD.

1. Describe its shape and mode of attachment to the thorax.

2. The two slender projections are the feelers, or **antennæ**. Observe how and where they are attached to the head. Use a lens to count the parts, or **segments**, of which each antenna is composed.

3. Note the situation and shape of the eyes. Examine one of the eyes under a microscope, using a one-inch objective; make a drawing of what you see. These eyes are **compound**, and each of the parts is called a **facet**.

4. Just in front of the compound eyes look for a pair of the simple eyes, the **ocelli**. Find a third ocellus on the head, using a lens if necessary.

5. At the lower part of the front of the head is a movable flap, the upper lip, or **labrum**; raise it with the dissecting needle. Observe how it is hinged; cut or break it off.

6. This lays bare the true jaws, or **mandibles**. Examine their black, toothed tips with a lens; find, by prying, how they move. Study their action in the live grasshopper, raising the labrum. Study carefully the way in which they move, and how they are hinged; then remove with the forceps, and again examine thoroughly.

7. Turn now to the back of the lower part of the head; pry back the lower lip, the **labium**; carefully remove it.

8. At the base of the labium is the brown **tongue.**

9. Attached to the base of the labium is a pair of short, jointed appendages, the **labial palps.** What is the relation between the tongue and the labium?

10. If the above-named parts have been carefully removed, there will remain one pair of appendages, smaller jaws, called the **maxillæ.** Make out that each maxilla consists of three parts: —

a. An outer, jointed part, the **maxillary palp.**

b. A spoon-shaped piece covering *c.*

c. The brown, incurved maxilla proper. Examine with a lens, then with forceps remove the whole maxilla, being sure to get the basal part.

11. Cut the head off a fresh specimen; lay it on the table and make a careful drawing of the face, naming all the parts.

12. Draw the head as seen from the side.

THE THORAX.

1. The wide collar, or cape, back of the head is the main part of the **prothorax**; make a drawing of it as seen from the side.

2. The remainder of the thorax is formed by the union of two parts, each bearing a pair of legs, the part to which the middle pair of legs is attached being the **mesothorax,** the hinder legs arising from the **metathorax.** Look for the line separating these two parts of the thorax.

3. Look just above the second pair of legs for a narrow opening, guarded by a pair of lips, which, in the live grasshopper, keep opening and closing; this is a breathing pore, or **spiracle.** Look for another spiracle on the soft skin under the posterior edge of the prothorax on each side.

4. Carefully compare the prothorax, mesothorax, and metathorax in size, shape, and structure.

THE WINGS.

1. Notice the position of the outer (upper or anterior) wings, and their mode of overlapping.

2. With the forceps seize one of the outer wings by its lower edge, near the anterior end, and draw it horizontally forward, till it makes a right angle with the body, and pin in this position. Seize the inner wing by its lower edge near the posterior end, and pull forward to its fullest extent, observing how it is folded; pin this wing as expanded, and make a drawing of both wings as thus seen. Cut a piece of paper the same size and shape as the inner wing, and fold it as the inner wing is folded.

3. The framework of the wings is composed of **veins.**

4. Compare the inner and outer wings in size, shape, color, texture, position, and use.

THE LEGS.

1. Note their number, arrangement, and mode of attachment.

2. Study carefully one of the hind legs.

a. A short segment, near the body, is the **coxa.**

b. A smaller segment is the **trochanter.**

c. The large segment is the **femur.**

d. The slender segment is the **tibia.**

e. The remainder is the foot, or **tarsus**; count its segments, and examine thoroughly, using a lens. Examine the joint between the femur and tibia, moving the parts back and forth. Note, also, how these parts fit together when the leg is drawn up. Remove a hind leg, and make a drawing showing all these parts.

3. In how many ways does the grasshopper travel? In what order are the legs moved in walking?

4. Grasshoppers make a shrill sound (stridulation) by rubbing the inner surfaces of the hind legs against the outer wings.

5. In what different ways does the grasshopper keep from slipping when it jumps? Remove the legs and wings; make drawings of the thorax as seen from the side, from above, and from below.

THE ABDOMEN.

1. Count the abdominal rings.

2. Observe two grooves running along the under surface of the

abdomen. The under part of the abdomen, included between these grooves, is the **sternum**, the side of the abdomen is called the **pleurum**, and the upper part is the **tergum**.

3. Just above the groove that separates the sternum from the pleurum is a row of small holes, the breathing pores, or **spiracles**; count them.

4. In a live specimen, watch the movements of breathing. All insects breathe by means of a complicated system of air tubes, the **tracheæ**, which branch from the spiracles throughout the body. Can the grasshopper be drowned by holding its head under water? Connected with the air tubes, in grasshoppers and other strong flying insects, as bees and flies, are large air sacs, which fill with air, and are said to aid, like balloons, in keeping the insect in the air. By carefully cutting away the roof of the abdomen, these air sacs may be seen, marked by their white walls; the white air tubes, or tracheæ, may also be readily seen.

5. Under the bases of the wings, on the first abdominal ring, is a pair of thin, shiny, oval membranes, the **tympana**, or eardrums. The inner surface of each tympanum is connected with a nerve.

6. The abdomen of the female ends in four points; in laying the eggs these points are first pressed together, then thrust into the ground, and then separated; this process is repeated till a hole is made, sometimes as deep as the abdomen is long, at the bottom of which the eggs are deposited, passing out between the four points, which together are called the **ovipositor**. The males are smaller than the females. Draw the abdomen, as seen from the sides, of both the male and the female. Take now an entire specimen and draw a side view of it.

INTERNAL STRUCTURE OF THE GRASSHOPPER.

This work would better be done after the student has dissected the crayfish. Dissect under water in the dissecting pan.

1. Get a large female grasshopper, freshly killed. Cut off the wings and place the specimen, back uppermost, in the dissecting

pan; pin the hindermost ring of the abdomen firmly to the bottom of the dissecting pan; turn each hind leg outward and pin down. With sharp, fine-pointed scissors, cut through each side of the roof of the next to the last abdominal ring; lift, with the forceps, the cover of this ring; continue to cut forward, on each side of the abdomen, pulling the tergum upward and forward as it is loosened. Thus carefully unroof the whole abdomen.

2. The heart is a delicate tube, running along just under the tergum, and probably was torn away with the tergum.

3. On each side there is a row of air sacs, with their white air tubes.

4. In the anterior part of the abdomen a mass of yellow eggs is usually to be found; this mass may be easily separated into two parts, right and left, from each of which a tube, the **oviduct**, leads to an opening between the parts of the ovipositor.

5. Under the eggs is the dark **intestine**, running lengthwise.

6. Remove the roof of the thorax; more air sacs should be found here. In the upper part of the thorax are the white **muscles** which move the wings. Removing these muscles exposes more of the digestive tube; as the food is swallowed, it passes upward into a brown tube, which soon turns backward into the thorax; in the prothorax, the enlargement is the **crop**, in which is produced the dark liquid which the grasshopper ejects from the mouth when held captive. The crop may be removed, split open, washed, and examined under the microscope with a half-inch objective to show the rows of hooked teeth with which it is provided. A little farther back the digestive tube is surrounded by a set of double cone-shaped pouches, which extend parallel with the main channel of the digestive tube. These are the **gastric ceca**. Behind them is the stomach, followed by the intestine. The products of digestion pass through the coatings of the digestive tube, and mingle with the currents of blood which pass along the ventral and lateral parts of the body.

7. The veins of the wings are air tubes, and are very different from the veins in our bodies.

8. The nervous system of the grasshopper consists mainly of a white cord extending along the floor of the whole body cavity. In most of the abdominal rings the nerve cord has enlargements called **ganglions**, from which nerves branch to the surrounding parts.

THE DEVELOPMENT OF THE GRASSHOPPER.

1. Late in summer watch grasshoppers to discover the process of laying eggs. If the eggs can be obtained, keep them till they hatch, and watch the growth of the young.

2. Early in the season catch a number of as young grasshoppers as you can find; cage and feed them, and watch their growth. What changes take place during development?

GRASSHOPPER CARD.

Take a card six inches by four. Make a faint mark lengthwise in the middle to aid in placing the parts symmetrically. Separate the parts of the grasshopper, and place them on the card in their proper order. Before beginning, plan the whole arrangement. First, cut off the head; leaving a central place for the head, remove the mouth parts, pasting each to the card as it is removed. In separating the parts use the forceps, being careful to get hold of the very base of each piece; then, holding each part with the forceps, dip the side that is to go next to the paper into the glue, and carefully place just where it is to stay. This method avoids smearing the card. Avoid getting too much glue. The mouth parts should surround the head; the wings should be opposite the parts to which they were attached, as also the legs. The legs should be separated to show all the segments; the thorax should be separated into its parts, but the abdomen would better be kept entire. As the parts become very brittle when dry, it is well, if the card is to be kept, to make a little bridge of a slip of paper, on which to string the rings of the thorax and abdomen. The soft parts should, of course, be removed. To preserve the card, place it in a shallow box and fasten it to the

bottom. Perhaps the best way is to make a glass cover to the box and then seal it, dust and moth proof, by means of passe partout binding.

Topics for Reports.—The Rocky Mountain Locust Scourge. Cockroaches. The Mole Cricket. Walking Sticks. Katydids. The Praying Mantis.

CHAPTER III.

INSECTA (*Continued*).

THE CRICKET.

1. In what respects are the cricket and grasshopper alike?
2. In what respects do they differ?
3. The female cricket has a long, slender ovipositor. Compare its parts with the parts of the grasshopper's ovipositor, picking them apart with a dissecting needle. Use a lens.
4. A pair of tapering, jointed projections from the abdomen are the **stylets**. Of what use are the stylets?
5. Compare the wings of the male and female. Look on the under surface of the outer wings of the male for a vein, running crosswise, near the anterior end, which has on it a row of teeth. By rubbing this **file** on the veins of the other wing, the cricket makes its chirping noise. Watch crickets to see how the wings are managed during this process.
6. With a lens look for the so-called hearing organ on the tibia of each fore leg.
7. Make a drawing showing all that can be seen from above (dorsal view), and name all the parts shown.

Grasshoppers and crickets belong to the order of insects called **Orthoptera**, or straight-winged insects.

THE DRAGON FLY.

1. Compare the shape and relative size of the parts of body with those of other insects. In some dragon flies the eyes have as many as 12,500 facets each.
2. What kind of mouth parts has the dragon fly?

3. How does the dragon fly compare with other insects in power of flight? To what bird should the dragon fly be compared in its habits?

4. Has the dragon fly a sting? Is it dangerous to man in any way?

5. Watch the dragon fly dipping the end of its abdomen into the water to lay its eggs. Compare the ovipositor with that of the grasshopper.

6. The larva of the dragon fly is called a **nymph**. It may be found on the bottoms of ponds and streams, and is very noticeable on account of its wide head and prominent eyes, wide abdomen, and short wings.

7. When the larvæ are ready to transform, they crawl up out of the water, their skins split along the back, and the adult dragon flies escape, leaving their dry, empty skins, which may be found clinging to the stems of water plants, projecting logs, or rocks.

8. Draw a dorsal view.

9. The dragon fly belongs to the order **Odonata**, or nerve-winged insects.

THE SQUASH BUG.

1. Find the sucking tube bent back under the thorax.
2. Are there both simple and compound eyes?
3. What peculiarities of the prothorax?
4. Draw a dorsal view, showing how the wings overlap.
5. Fasten the squash bug's wings out at right angles to the body, and make another drawing, showing how the outer wings appear when extended, and how the inner wings are disposed.
6. Draw a ventral view.

Look for eggs. Compare young and old squash bugs. Squash bugs belong to the order **Hemiptera**, or half-winged insects. What is the propriety of this name? Insects belonging to this order are the only ones that are properly called "bugs."

Topics for Reports. — The Periodical Cicada. Plant lice. The Cochineal Insect. Scale Insects. The Chinch Bug.

THE BUTTERFLY.

The large brown monarch butterfly, or "milkweed butterfly," with dark markings along the veins of the wings, is a good one to study.

1. Notice the position of the eyes, and their relative size.

2. Where are the antennæ attached? Compare with those of the grasshopper.

3. The short projections in front of the head are the labial palps.

4. Between the palps is the coiled sucking tube; uncoil, and examine it.

5. The wings: —

(*a*) Their shape and their mode of overlapping.

(*b*) The dark, shiny veins; where are they strongest?

(*c*) Scrape some of the scales off a wing; examine under a high power of the microscope, making drawings.

(*d*) Examine with a low power of the microscope a piece of a wing, with the scales on it, to see how they are attached and arranged. Look at a part of the wing where the scales have been removed.

6. Spread the wings of a butterfly, and draw them as seen from above.

7. Examine the legs, and compare their use in this insect and others.

8. Make a drawing of the butterfly as seen when at rest, naming all the parts visible.

9. Compare the colors and markings of the upper and lower surfaces of the wings.

10. Carefully compare a moth and a butterfly.

11. Butterflies and moths belong to the order **Lepidoptera**, or scaly-winged insects.

The orders of insects are divided into **families**; this butterfly belongs to the family **Nymphalidæ**.

Families are divided into **genera**; this butterfly belongs to the genus **Anosia**.

Genera are divided into **species**; this species is **plexippus**. So his butterfly belongs to the class, Insecta; order, Lepidoptera; amily, Nymphalidæ; genus, Anosia; species, plexippus.

The males are distinguished by an elevated black spot on one of the veins, near the middle of the hind wings.

Where is this butterfly found most abundantly?

Development of the Cabbage Butterfly.

The cabbage butterfly is small, yellowish beneath, paler above, with black tips to the anterior wings. The male has one round black spot only on each upper wing, while the female has two, and sometimes three.

1. Open the abdomen and look for eggs. They are yellow, oval bodies, ribbed lengthwise, with cross markings on the ridges, resembling stunted ears of yellow corn. Look also for these eggs on cabbage leaves, or where the butterflies are seen hovering. Watch the butterflies closely as they light on the cabbage leaves, to see the egg deposited on the leaf; on which side of the leaf are the eggs usually laid? How are they fastened to the leaf? Make a drawing of the egg as found attached to the leaf.

2. Get a chalk box with a sliding cover; substitute a glass cover a little longer than the box. Keep the box on end, so that the door will keep closed, yet may be easily opened. Put into this box a cabbage leaf with eggs on it; examine several times a day. What becomes of the egg? In another box, similarly arranged, put some large cabbage worms; give them fresh leaves every day, and keep the box in a light, well-ventilated room. Watch closely, and keep record of the date of the beginning of the experiment, and note the date of any change; describe carefully all actions and changes in the worms. Make careful drawings of each stage of growth:—

(*a*) The egg.

(*b*) The larva, at different stages of growth; keep one worm in a cage by itself, and make a drawing every third day.

(*c*) The pupa, showing how it is suspended.

(*d*) The perfect butterfly.

3. The cabbage butterfly belongs to the family Pieridæ, genus Pieris, species rapæ.

There are several species of the genus Pieris, just as there may be several persons in one family; as in a directory we read: "Smith, Charles," "Smith, Edmund"; so we read: Pieris rapæ, Pieris protodice.

What is the meaning of the word "rapæ"?

Occasionally a larva will fail to go through its proper changes; this is generally caused by some parasite, the most common of which is an ichneumon larva. The adult of some ichneumon fly lays it eggs on the body of the cabbage worm; these eggs hatch out as worms, bore into their host, and live on the juices and tissues of the cabbage worm, till it dies from exhaustion (though the cabbage worm often lingers, and the parasitic larvæ complete their transformation first), and the parasitic larvæ become pupæ, and hatch out as perfect ichneumon flies.

Look for holes in **pupæ** which fail to complete their transformation; often holes may be found in them where the ichneumon flies have made their escape. If a pupa blacker than usual be found, put it in a vial, or pill box, and catch the ichneumon flies as they emerge.

Topics for Reports. — The Clothes Moth. The Silkworm. The Tent Caterpillar. The Codling Moth. Cecropia. Polyphemus. Cutworms.

THE HOUSE FLY.

The Parts of the Body.

1. The **head**, the foremost, or anterior, part.
2. The **thorax**, or middle portion.
3. The **abdomen**, the hinder, or posterior, part.

The Head.

1. Examine the eye with a strong lens, and under a low power of the microscope, to discern its parts or facets. What shape have the facets?

2. Cut off the head, lay it on a glass slide, and with a one-inch objective examine the short antennæ in front of the head.

3. Look on the top of the head for simple eyes.

4. With a lens examine the under part of the head to see the tongue. How does it move? Remove it and look at it with a one-inch objective. How is the tongue used?

The Thorax.

1. How many legs are there? To what are they attached? How many segments has each leg?

2. The wings; how many are there? Back of each wing find a short membrane, the winglet. Note the folded portion connecting the wing and the winglet.

3. A little farther back are two slender stalks ending in rounded knobs; these are the **balancers**, and are considered as representing the hinder wings found in most insects. Note the effect of removing the balancers.

4. The wings describe a figure 8 in flying, and make over 300 vibrations (*i.e.* go up 300 times and down 300 times) in a second.

5. On each side of the thorax, just back of the head, find a narrow opening with a yellow, liplike border; examine closely with the aid of lens and microscope. It is a breathing pore, or spiracle.

The Abdomen.

Are there spiracles on the abdomen? How many rings has the abdomen? Draw the fly as seen from above (dorsal view).

The house fly lays its eggs about stables; after a day or two the egg hatches out as a maggot, which eats voraciously and grows rapidly; in about a week it ceases eating, becomes dry and brown, resembles a seed, and does not move; from this **puparium** the fly emerges. The adult fly is short-lived, tho some live over winter. Watch the development of the egg which the flesh fly lays on meat and dead animals. How many kinds of flies do you know? How do they differ? How does the fly walk on the

window pane? Examine the feet? In what order does the fly move its feet in walking? For the study of this point, take a fly that is sluggish from cold, or from partial drowning. Do flies, on the whole, injure man, or benefit him? Flies belong to the order **Diptera**, or two-winged insects. What other insects have but two wings?

Topics for Reports. — The Mosquito and Disease. House Flies. Horseflies. Botflies.

THE BEETLE.

1. What are the characters that appear peculiar at first sight?

2. Note the position and shape of the **eyes**.

3. The **antennæ**, their attachment, parts, and mode of extension.

4. A small upper lip, the **labrum**.

5. A pair of strong jaws, the **mandibles**, often very large, and projecting forward as pinchers, or "horns." How do they move?

6. Back of these are two small jaws, the **maxillæ**, bearing a pair of jointed appendages, the **maxillary palps**.

7. Back of (posterior to) the maxillary palps is another pair of similar appendages, the **labial palps**.

8. The part of the body back of the head is the **prothorax**. Why not call it the thorax?

9. Pry up the hard outer wings. How do they meet each other? Each outer wing is called a wing cover, or **elytrum**. In what direction does the beetle move the elytra in raising them? How are they held during flight? Do they rise vertically?

10. How are the inner wings folded? Compare the inner and outer wings in length and size. Cut a piece of paper of the same shape as the inner wing, and fold it as the inner wing is folded. How does the beetle perform the act of folding the inner wings? Capture live beetles and watch this process.

11. Make a drawing of the back, with the wings closed; another drawing, with the wings fully expanded, as in flight.

12. Count the segments of the legs. Examine each segment closely. Seize the foot of one of the hind legs with the forceps,

and pull it about in all directions, to see how many joints the leg has, and what motions are allowed by each joint. The segment nearest to the body is the **coxa**. Then come, in order, **trochanter**, **femur**, **tibia**, and **tarsus** (foot).

13. What marks the line of division between the thorax and abdomen?

14. Draw a ventral view on a large scale, showing especially the parts of the legs, and the mouth parts.

15. Watch a crawling beetle, to see in what order the legs are moved.

16. What can you tell of the habits of beetles? The different kinds of beetles, and their development? What is a grub? Compare beetles with other insects in strength. The large beetles are good insects for dissecting, to show the internal structure. Beetles belong to the order **Coleoptera**, or sheath-winged insects.

Topics for Reports. — Fireflies. Blister Beetles. The Carpet Beetle. Water Scavenger Beetles. Whirligig Beetles. Carrion Beetles.

THE BUMBLEBEE.

1. Find three simple eyes on the top of the head. How are they arranged?

2. Describe the antennæ.

3. The mouth parts: —

a. A pair of true jaws.

b. The long, hairy tongue.

c. Above the tongue the two blades of the maxillæ.

d. Below the tongue two thin, narrow labial palps.

The last three form a proboscis. Pick the parts asunder, and make a drawing of the front of the head, showing all these parts.

4. How does the bee take its food? Is the honey stored by the bee the same as the nectar taken from the flower?

5. Compare the segments of the legs with those of the grasshopper. How does the bee get pollen? What does the bee do with the pollen?

6. Examine the wings; compare the front and hind wings.

7. Get a bumblebees' nest; examine the contents of the cells, and note the different stages of development of the young bees.

8. The sting is a modified form of ovipositor. Near its base are poison glands, and a sac for storing the poison. Remove a sting with the poison sacs and examine under a low power of a microscope.

9. How do bees compare with other insects in intelligence?

10. Ants, bees, and wasps belong to the order **Hymenoptera**, or membrane-winged insects.

Topics for Reports. — Bumblebees. Wasps. Solitary bees. Ants.

STUDY OF THE DEVELOPMENT OF THE HONEY BEE.

Through the glass sides of the hive observe the comb. The depressions or holes in it are the cells. Find cells that are empty, others that are partially filled with a substance whose glassy surface reflects the light. These cells contain honey. Find cells apparently empty, but which upon close observation are found to have a small, oblong, white body at the bottom of them. These may be seen attached by one end to the bottom of the cell near its center. They are not as large as the head of a pin, and are often overlooked. They are eggs. Record the date upon a small piece of paper, and paste it on the glass opposite the cells containing eggs, and note the changes from day to day. Determine the number of days elapsing between the time the egg was laid and the time of hatching. Make several trials. Begin with empty cells, and note when the eggs are laid, as some of the eggs may have been in the cells a day or two before you found them. Determine the length of time the young bee is in the grub or larval stage. The larva may be seen one or two days after hatching, floating in a small drop of gray-colored liquid at the bottom of the cell. Note its rate of growth. What care has it received? Has it been nursed, fed, and cared for, or has it, like Topsy,

"jest growed"? Find other cells near the brood (by brood is meant young bees in all stages of development) which are partially filled with a yellowish or brownish pastelike mass. This is stored pollen, or "bee bread." Its color varies according to the kind of flowers from which it is gathered. Now look for larvæ in all stages of development, from the smallest, which are little larger than the egg from which they came, to those which almost fill the cells they occupy, and in which the segments may be easily counted. Find other cells each covered with a brown cap. Observe them closely from time to time, and try to determine what they contain. Cells near the ends and top of the brood frame, which are covered with white caps of wax, contain honey. The caps of the latter may appear dark if the honey touches the caps, but usually there is an air space between the honey and the caps, and the caps appear white. Look for both of these conditions. What changes have you noted through a period of ten or twelve days in the cells in which you first found eggs? Can you now see the interior of the cells? Can you discover the bees placing brown caps on cells containing the largest larvæ? If so, note the date and determine the length of time the caps remain on them. Determine how and by whom these caps are removed. Watch to see some of the occupants of these cells come out. Note any difference in appearance between these and older bees. If these directions have been followed through a period of several weeks, you have observed all of the stages of development of a honey bee, and noted the length of time the young bee was in each stage. Which of these stages corresponds to the caterpillar stage of a butterfly? Which to the cocoon stage of a moth?

Honey Bees at Work.

Watch the bees as they come and go at the entrance of the hive. Dust a little flour upon some that are entering, and note to what part of the comb they go. Determine, if you can, whether they remain in the hive for some time or soon leave it again. Look for bees coming in loaded with yellowish or brownish pellets attached

to the outside of the large segments of the hind legs. Where and how do they unload? What are they carrying? Why do they bring this substance? In the latter part of the season bees sometimes carry propolis, a sort of glue, in the manner above suggested. This latter substance is used to seal cracks and crevices. Observe that some of the bees on the comb move about from cell to cell, putting their heads into the cells where there are larvæ. What is the work of these bees? Are they young or old bees? What is pollen? What is nectar? How does honey differ from nectar? What is beeswax? Is it gathered by the bees, or do they make it? What difference in color between new honeycomb and the brood comb you have just been studying? Why this difference in color?

Study of the Structure of Honeycomb.

Obtain two pieces of empty honeycomb, one with cells the same size as those in the brood comb in the hive, and the other with cells somewhat larger. Note the shape of the cells. What geometrical figure is represented by a cross section of a cell? Why not have round or square cells instead of this form? Lay a foot rule upon a row of cells across the face of one of the pieces of comb. How many cells in one inch? Make several measurements to obtain an average number. The average diameter of the cells may be expressed by what common fraction? Repeat with the other piece of comb and compare results. For what especial purpose do the bees use each kind? Do they ever use both for the same purpose? Draw a face view of each kind of comb, being careful to show correctly the relation of each cell to the cells adjoining it. Cut a piece of comb so as to show a freshly exposed edge. Note the shape of the bottom of the cell and the relation of those on one side of the comb to those on the other. Draw an edge view of a piece of comb, using care to show this relation. Note the number of parts in the bottom of each cell. Shape of each part. Make a pinhole in each part of the bottom of a cell. Turn the comb over and find how many cells have holes in the

bottom. Why this number? What new fact in regard to the relation of the bottom of a cell to the cells on the opposite side of the comb? Why should the bottom of a cell be of this form and not flat? Why this relation to the cells on the other side?

THE ANT-LION.

Field Study of the Larva. — In dry, sandy places look for conical depressions, as evenly made as if rimmed out by a mechanic. Many of these pits may be found near each other, in the neighborhood of ants' nests. Drop a few grains of sand into the center of the pit, looking closely meanwhile, for the protruding jaws at the bottom of the pit.

Quickly scoop up the whole pit, aiming to go an inch deeper than its greatest depth. This can be done very well with the hand, though a garden trowel is best. A tin cup or dipper would serve very well. Sift the sand thus scooped up through the fingers or over the edge of the hand, and look closely for the dull gray larva of the ant-lion (Fig. 16). It has an oval body, and a pair of long, hooked jaws. Place the larva on sand held in the hand, cup, or can, and see how it buries itself.

Home Study of the Ant-lion Larva. — Take several larvæ home. Place each on sand in a separate tumbler or can. Two or three inches deep will be enough. Watch again how the larva buries itself. Watch patiently to find how it digs the pit. Drop an ant, a crippled fly, or almost any small insect into the pit and see what the larva does. How does it eat? How much of its victim does it consume? For the appearance of the adult ant-lion see Fig. 15, in the descriptive text.

REVIEW OF INSECTS.

Take any insect not yet studied, and examine it thoroughly. Write a full description, and make drawings of it. Which of the insects previously studied is this most like? To what order, then, does it probably belong?

Select two pages in your notebook that face each other. On the left-hand page make a list of characters common to all the insects you have studied, numbering the points; on the right-hand page write briefly the characters peculiar to each insect. The first list ought to be a very nearly correct definition of an insect, so far as external features are concerned. The second list should serve as a definition of each of the orders of insects.

All the orders of insects belong to the class **Insecta**.

Write now a list, in vertical series, of the orders of insects studied, with the name of the insect representing that order opposite it, and include all within a brace opposite the word **Insecta**.

Read *Insect Life*, Comstock.

CHAPTER IV.

ARACHNIDA AND MYRIAPODA.

STUDY OF LIVE SPIDERS.

Spiders and Spider Webs. — Find a spider at home near you, where you can conveniently watch it for some time each day. What is the shape of the web? Do all spiders make the same kind of a web? Does the same spider always make a web in the same way? How is the web situated? Does the spider stay on the web? If so, on what part of it? What reason for this position? If you cannot find a spider beginning a new web, destroy a web and watch to see if a new one is begun soon. Does the spider take the same place for the new web? How does it begin the work? Is every part kept as first made, or is any part comparable to the scaffolding erected by the carpenter? Do spiders repair broken places in webs? If so, how is this done? How is food secured? Watch the whole process of capturing and eating food. Does the capturing of the food injure the web? Are spiders equally active at all times? Visit a spider in the evening and see if it is awake, and "ready for business"? Are spiders affected by cold? Do they like sunshine? Do they live over winter? What can you learn about the development of spiders? Why are there sometimes so many spider webs floating in the air? What relation have these floating webs to the weather? Are these floating webs of any use to spiders? How are they set afloat, and what keeps them afloat? Can you discover the beginning of such work? How and where do spiders lay their eggs? Watch the development of the eggs.

External Features of the Spider.

Spiders are best preserved in alcohol, as they shrink in drying.

1. The anterior division of the body is the **cephalothorax**, or united head and thorax.

2. The large posterior division is the **abdomen**.

3. How many legs are there? To what are they attached? How many segments are there in each? Examine the feet under a microscope. Make a drawing of one of the feet. Can a spider climb out of a tumbler? Compare it with the beetle in this respect.

4. With a dissecting needle pry apart the mandibles, at the front of the head. The duct of the poison gland opens at the tip of each mandible.

5. Back of the mandibles find a pair of small jaws, the **maxillæ**.

6. To the maxillæ are attached a pair of jointed appendages, resembling a pair of legs, the **maxillary palps**.

7. With a lens look for the simple eyes above the jaws. How many are there, and how are they arranged?

8. With a lens examine the **spinnerets** at the posterior end of the abdomen. With a pair of forceps hold a live spider by one leg, and watch the beginning of spinning.

9. Besides air tubes, some spiders have one or two pairs of **lung sacs**, composed of several leaves, into which blood flows, and is thus aërated.

Place the description of the spider alongside the list of characters common to insects, and note what features are common to the spider and all the insects; also the points wherein they differ. Spiders belong to the class **Arachnida**.

Read Emerton's *Spiders, their Structure and Habits*.

MYRIAPODS.

One form of "thousand legs," commonly found under stones and under the bark of dead stumps and logs, is well known by its cylindrical body, by its numerous, short, hairlike feet, and by its

habit of coiling its body into a spiral when disturbed. This is a milliped.

1. How many segments has the body?

2. How many appendages has each segment?

3. Make a drawing of the thousand legs.

4. What are the chief differences between this animal and insects?

Another common form of thousand legs is that called centiped. It is, when full grown, about an inch long, with a broad, flat head, a brown, shiny back, the segments being generally about the same size, with one pair of jointed appendages to each segment. The antennæ are many-jointed. It is found under boards and about rubbish and manure heaps, where it feeds on insects and earthworms. It usually runs actively when uncovered.

1. Examine the jaws and mouth parts carefully; how many pairs of jaws are there?

2. With a lens examine the legs. How many are there?

3. What kind of eyes are there? How many, and how placed?

4. Arrange the legs so they can be distinctly seen, and make a drawing as seen from above.

5. Make an enlarged drawing of the mouth parts as seen from below.

6. What are the differences between this form and the thousand legs mentioned above?

7. In what are the two alike? Both belong to the class **Myriapoda**. Carefully compare them with the insects, and make a list of points common to insects and myriapods; also a list of the characters which insects have and the myriapods do not have; and a list of points peculiar to myriapods.

CHAPTER V.

CRUSTACEA.

STUDY OF THE LIVE CRAYFISH.

Field Study.

Where to find Crayfishes. — Look under stones in shallow creeks, under ledges of rock, or overhanging banks of streams. Remember that crayfishes are nocturnal and are usually hiding during the daytime. Note all the kinds of places in which you find them, and where they are most numerous. Are they in deep or shallow water? In clear water or muddy? In fresh water or foul? In quiet water or in rapid currents? Over mud, or gravel, or sand?

How they Escape. — In turning over stones or tin cans in a stream, note closely how the crayfish escapes. Which end goes foremost? What is the chief organ of locomotion? How is this used? How far does a frightened crayfish ordinarily go before stopping, if not closely pursued? Does it stir up mud in its flight? If so, how is this done? Does the stirring up of mud benefit the crayfish? If the crayfish goes some distance, is the rate of motion uniform? Explain.

Color of the Crayfish. — Note the color of the crayfish in relation to its surroundings, especially the color of the bottom over which it passes. Is its color an advantageous one? What if it had the color of a boiled crayfish? Are all crayfishes of the same color? How account for the difference?

Crayfish Holes. — Where are these most abundant? Do they all have "chimneys"? Is the chimney of the same color as the surface soil? How high are the chimneys? Are these built

during the day or during the night? How does the crayfish build the chimney? How deep are the holes? What are they for? Do all kinds of crayfishes dig holes? In what part of the hole does the crayfish stay? Are the holes used equally at all seasons?

Molted Shells. — If you find what appears to be a dead crayfish, examine it carefully to see whether it is really a dead animal or only the cast-off shell. Do you find any dead ones?

Enemies of the Crayfish. — Have you seen any animal eating or attacking a crayfish? Or any evidences of such action?

Home Observations.

Walking. — If one has no aquarium, a dish pan or homemade trough serves very well. Watch a crayfish crawling in the water. What appendages are used? Can it walk in other directions than head foremost? Are the legs moved in regular order? Place a crayfish on the floor. Does it walk equally well in water and out? Why should there be a difference?

Swimming. — Frighten a crayfish by thrusting a stick at it to see how it swims. Study closely the parts used and their action. Suppose a crayfish could propel itself rapidly forward, how would the resistance compare with the resistance it meets while going backward? Note closely the condition and position of the tail fin while making the stroke and while darting through the water between strokes. Observe all the points of structure that aid the efficiency of the stroke? What is true of the amount of resistance in the recover stroke? With the thumb and finger, take a crayfish just back of the big pinchers and hold it with the head up, so that the tail fin is covered with water; if it is now excited, the effectiveness of the tail fin will be well demonstrated.

Mode of Defense. — With a stick or pencil, make motions at a crayfish to see how it defends itself. Allow it to grasp a pencil to show the strength of its grip. Does a crayfish prefer to fight, or would it rather avoid an attack? In an aquarium does a crayfish

stay in open places, or where the light is strongest, or does it seek sheltered places?

Feeding. — Offer a crayfish various kinds of food, bread, meat, cheese, vegetables, etc. Find what it prefers. Learn how it eats, what organs are used and how they are used. Does a crayfish eat much or little? Is it a rapid or a slow eater? Examine the mouth parts in this connection. (In these experiments be careful not to let the water become foul.)

The Water Currents to the Gills. — While a crayfish is at rest in shallow water, carefully introduce a few drops of ink near the bases of the hinder legs. Where is it drawn in and where does it reappear? Try placing the ink at various points along the edge of the carapace. Place a crayfish in a candy jar. Watch it from the front and below to see the vibratory motions of the outer branches of the maxillipeds. Their motions indicate the rate of movement of the gill scoop, or gill paddle, within. Count the vibrations for a minute. How is it that a crayfish, while breathing by gills, can live so long out of water?

Senses. — Note the range of motion of the eyes. Can an enemy approach a crayfish from any direction without being seen? Can a crayfish see small objects as well as large ones? Does it notice slow motions as readily as quick ones? Does a crayfish see where it is going when it is frightened and darts backward by swimming?

What advantage is there in having the eyes on movable stalks? What disadvantages? In what ways is the eye protected? Touch one of the eyes. What follows?

With a straw, broom-straw, or feather, test the sense of touch over all the outside of the body. Where does the crayfish seem most sensitive to touch? Is there any special reason for having two pairs of "feelers"?

Which reach farther forward, the big claws or the antennæ? Can the antennæ extend back as far as the tip of the tail fin?

Make noises near the crayfish to test its sense of hearing. In

these experiments take care not to produce such vibrations of air, water, or mud as might effect the sense of touch.

Test the sense of smell by placing various odorous substances near the crayfish, when in air as well as in water. Is any attention paid to scents?

Recall any choice of food the crayfish has made? Is this choice determined by a sense of taste? Place various substances that affect your sense of taste on the crayfish's food. Does it make any difference in his choice? Place on the mouth organs drops of various liquids that affect your taste. Is the crayfish affected thereby?

Molting. — Sometimes when one has left a single crayfish in an aquarium he is surprised to find two. The molted shell looks like a complete crayfish. Watch a crayfish closely for this change. Before the molt a crayfish is dull and quiet. What are the first stages of the process, and in what order does he cast off the old shell? Feel of the newly emerged animal. For several days test the hardness of the shell. How long does it take for a "soft-shell" crayfish to become a "hard-shell"? What makes the shell hard? Drop a piece of the old shell in weak hydrochloric acid (vinegar will serve). Hold a piece of shell in flame. Does it burn?

Development. — Find a female crayfish with eggs. To what are the eggs attached? Watch till the eggs hatch out. How long are the little crayfishes when first hatched? Do they go free or remain attached to the mother? If they separate from her, do they return to her? Does she make effort to keep near them or keep them near her? Does she feed them? What do they eat at first? Do crayfishes ever eat each other? Do they kill each other?

External Parts of the Crayfish.

1. Note the two distinct parts of the body, (1) the anterior, rigid part, the **cephalothorax**; (2) the posterior, flexible part, the **abdomen**.

2. The covering of the cephalothorax is the **carapace**. Running across the carapace is the **cervical groove**. The anterior projection of the carapace is the **rostrum**.

3. Bend (flex) the abdomen, and straighten (extend) it repeatedly, observing how the segments are jointed together, and how they move one upon another. Count its rings or segments.

4. Separate the third ring (counting from the front) from the rings in front of and behind it. To do this hold the cephalothorax and fore part of the abdomen by the thumb and fore finger of the left hand, with the posterior end of the abdomen projecting toward the right hand; then, grasping the dissecting needle firmly with the right thumb and forefinger, thrust the point of a dissecting needle obliquely forward between the third and fourth segments, and work it up and down, severing all connection between them without breaking either; with scissors cut the membrane between the under sides of the rings, and entirely separate them. In like manner detach the third segment from the second. The ring has these parts:—

a. The upper part, the **tergum**.

b. The under part, the **sternum**.

c. The side piece, the **pleurum** (projecting downward).

d. Two appendages, the **swimmerets**. (See Fig. 46.)

5. Observe that each swimmeret has a main stalk, the **protopod**, and two branches, an outer, or **exopod**, and an inner, or **endopod**; examine these appendages thoroughly. Lay the ring on its front side, make the branches of the swimmerets diverge enough to appear distinct, and make a drawing of the whole ring as seen from behind.

Compare the other segments of the abdomen with the third.

In the male the appendages of the first and second rings are larger than those of the other segments and are specially modified. In the female the swimmerets of the first and second abdominal segments are smaller than the others. The abdomen of the female is wider than that of the male, probably for the purpose of protecting the eggs and young, which are attached to the swimmerets.

6. Study carefully the structure and action of the **tail fin.** Its middle piece is the **telson,** underneath which is the external opening of the intestine, the anus.

Remove the telson, and without disturbing the side parts of the tail fin, separate the sixth abdominal ring from the fifth. Now carefully compare this (sixth) ring and its appendages with the third ring and its appendages.

7. Are the appendages of the thorax borne upon rings like those of the abdomen? If so, where are the rings? With forceps seize the base of one of the hindmost pair of walking legs, and move it backward and forward; are these borne on a distinct ring? Carefully clean the sternum between the other walking legs, and look closely for indications of rings.

8. With the forceps break away one side of the carapace, beginning at the lower edge. This lays bare the white, feathery **gills.** Cover the specimen with water in the dissecting pan to show the gills more clearly. Move the legs of this side back and forth, watching the gills.

9. Study now the hindmost of the walking, or thoracic, legs. Count its segments. Observe how the first segment is joined to the body. Flex the leg as far as possible, in every direction, noting the number of joints, and the motions allowed by each. With the forceps seize the squarish, basal segment of this leg, and pull off the leg.

10. Remove in like manner the legs in front of this, again being careful to get a firm hold of the short, wide segment next to the body. What is the relation between the leg and the gill nearest to it? Lay this leg on a paper in front of the one previously removed. In this way pull off all the legs of one side, from the hindmost to the foremost, laying them in order. Compare them all with the one first taken. In the legs bearing pinchers is there any real new part added, or is the pinching apparatus produced by some change in a part presented in all the legs? How do the legs which bear the big claws differ from the walking legs? Compare them, segment with segment.

11. Anterior to the big legs are several pairs of appendages surrounding the **mouth**. Probe between them to find the mouth. These mouth parts are numbered from the front, but on account of the way in which they overlap, it is easier to remove and study them in the reverse order.

12. The appendages just in front of the big claws are the hindmost of three pairs of jaw feet, or **maxillipeds**. Gently raise them to see how they cover the other mouth parts. Note that these maxillipeds, or foot jaws, have an inner branch (endopod), which meets the corresponding part of the opposite maxilliped, and an outer branch (exopod). Observe that both these branches are attached to one segment (protopod), next to the body. Seize this basal segment, and remove the whole maxilliped. Compare it with one of the swimmerets of the third ring of the abdomen. In the same way remove the second and first maxillipeds of this side, keeping them in order. Are there gills attached to the maxillipeds? Is there more than one gill on each leg? Are there other gills than those attached to the legs? Pick one of the gills to pieces under water to determine its structure. After removing the gills, look in this region for further traces of thoracic rings.

13. Anterior to the maxillipeds are two pairs of **maxillæ**. These are very thin, and lie close to each other, so that if great care be not taken, they are likely to be pulled off together. Investigate closely, and then, inserting the forceps well down, remove them, one at a time. Attached to the base of the hinder maxilla is a thin, double spoon-shaped structure, the **gill scoop**, or **gill paddle**. It lies in the front part of the cavity in which the gills are, the **gill chamber**. With the forceps move back and forth the second maxilla of the other side, to see how the gill scoop is thereby moved. The gill scoop, swinging back and forth, pushes the water out of the front end of the gill chamber. The water thus expelled is replaced by fresh water, which comes up under the lower edge of the carapace, about the bases of the legs; thus the gills are constantly bathed with water containing a fresh supply of oxygen.

14. The **mandibles** are short, hard, and toothed. Each mandible bears a jointed appendage, the mandibular **palp**, which curves around the anterior edge of the mandible in a groove. Move a mandible about to see how it is hinged.

15. Closely fitting against the posterior surface of each mandible is a thin, leaflike structure, the **metastoma**. The metastoma differs from the maxilla in pointing outward and in being undivided. Remove it and complete the series of mouth parts, — mandible, first maxilla, second maxilla, first maxilliped, second maxilliped, third maxilliped. R move the corresponding appendages of the other side, lay them in a row facing those of the opposite side as before removal, but not now overlapping each other, and make a drawing of the series, naming them.

16. The long projections in front of the head are the **antennæ**. Seize one of them with the forceps, and pull about in all directions, to make out the large segment, at its base, under the head. On this basal segment find a small white cone, with a hole at its summit. This is the aperture of the kidney, or **green gland**. Remove the antenna, with the whole of this big segment at its base. What, probably, is the use of the bladelike branch of the antenna just under the eye? Compare the antenna and its branches with a swimmeret.

17. Above the antennæ are the **antennules**.

18. In the base of each antennule, just underneath the eye, is the **ear sac**.

19. With the forceps pull the eye about to see its range of motion. Pull it out by its stalk, and examine with lens and microscope its black tip, or **cornea**. Each distinct area is a **facet**, and the eye is compound.

20. After removing the cephalothoracic appendages, and the carapace, carefully clean and thoroly examine the framework of the cephalothorax, still looking for traces of thoracic rings.

21. The skeleton of a crayfish, like that of insects, is an external skeleton, or *exo-skeleton*. Compare it with the internal skeleton, or *endo-skeleton*, of vertebrates.

Crayfish Card.

Get a piece of stiff, smooth cardboard six inches by eight; select some dark color such as will make a good background for the crayfish. With pencil make three fine lines lengthwise, one in the middle, the others an inch from the middle. Make a cross at the center of the middle line. Now dot all three lines at intervals of half an inch, starting from the center.

Separate the parts of a crayfish as in previous study. For this the specimen should be slightly moist. If too dry, it will be brittle. If too wet, it will stain the card. If the work is interrupted, it is well to keep the parts on a damp paper or cloth, and covered so they will not be scattered. The parts of a crayfish are so compactly put together that it is impossible to see them all, while in their natural place. One object of this work is to make a permanent preparation with the parts separated enough to show them distinctly. The crayfish is supposed to be crawling along the middle line of the card, and to have become dismembered and strung out. The carapace is to be in the middle line, with its hinder edge half an inch from the center of the card. The abdominal rings are to follow this at intervals of half an inch. The appendages are to be arranged along the side lines at intervals of one half inch, with their bases at the side line, and extending at a suitable angle forward. To support the carapace and abdominal rings, make a cardboard bridge of the same material as the card. This bridge should be just high enough to reach the under surface of the arch of the carapace. The rings should be strung on this bridge, and both the rings and the carapace sewed to the bridge at the top, with a thread of such color as to be as inconspicuous as possible. The ends of the bridge should be sewed to the card, and the lower edges of both rings and carapace fastened so they will not slip about. All needle holes through the card must be made from above to avoid leaving a rough place. Determine where each hole is needed, and pierce from the upper surface of the card, whether the thread is to be passed through from above

or below. In fastening the appendages, first decide just where the part is to lie. Then, directly under the basal part, make a hole from the upper side. Then pass the thread through, from below, over the appendage, and down again through the same hole. The loop thus made will hold the appendage securely and be little noticed if the thread has a suitable color. In this way fasten each of the longer legs at three points. Leave the eyes attached to the carapace, but arrange all the other appendages, from the antennules to the last thoracic legs. Label the whole series on one side, placing the name below each appendage.

Dissection of the Crayfish.

1. Place the crayfish in the dissecting pan, dorsal surface up, and cover it with water. Place a double-pointed tack astride the narrow part of each of the first pair of thoracic legs just back of the big pinchers. By pressing strongly with the thumb the tack can be set firm enough to need no hammering. Now pull the body of the crayfish back taut and tack firmly through the telson.

2. Insert the point of one blade of the scissors under the hinder edge of the carapace, about an eighth of an inch to one side of the middle line. Cut forward to the groove which separates the head from the thorax. Break away the whole of the side of the carapace. Push the gills downward, and cut them off at their point of attachment. Observe the thin wall separating the cavity in which the gills were, the gill chamber, from the body cavity. Clear away the other side likewise.

3. With the forceps pick away the narrow remaining strip of the carapace, *carefully*, as the heart lies just under it. The **heart** is an oblong, whitish body. Look for small white tubes, **arteries**, running forward from it toward the head. How many are there? Be on the lookout for other arteries. With the forceps gently lift the hinder end of the heart; note its angularity. Look for holes in the dorsal surface of the heart; how many do you find? Look also for holes on the sides and on the ventral surface.

4. Under the heart, and projecting in front of it, are the reproductive organs: in the female, the **ovary**, in which the spherical eggs may be distinguished; in the male, the whitish **spermary** occupies a corresponding position. The ovary sends downward on each side a tube, the **oviduct**, or egg tube, to the first segment of the third thoracic leg, where it opens externally. The **spermary** has a much longer, coiled white tube, which opens on the first segment of the hindmost thoracic leg.

5. Carefully cut away the roof of the head. The space within the head is almost completely occupied by the **stomach**, a roundish sac, with a thin wall, in which is a hard framework. Gently scrape away the soft tissues around the stomach, and examine it closely. Observe the narrow **gullet** or **esophagus** leading from the mouth to the stomach.

6. Along the sides of the posterior end of the stomach and the anterior end of the intestine lie the large digestive glands. They are yellow or greenish in fresh, reddish in alcoholic, specimens. Pick one of these masses to pieces to learn its structure. Find the duct leading from each gland into the intestine.

7. Observe the white **muscles** which extend forward from the abdomen along each side of the body cavity.

8. Beginning at the front end of the abdomen, close to each side, cut with scissors through the roof of the abdomen to the telson. Seizing the forepart of this roof with the forceps, carefully lift it and turn it backward. A thir layer of white muscle may adhere to it, or may remain connected with the organs in the abdomen. This is made up of the muscles that straighten (extend) the abdomen. Pick them away carefully with the forceps.

9. Running lengthwise, in the middle line, is the **intestine**, a thin-walled tube, often of a dark color from its contents. Trace it back to the anus and forward to the stomach. Carefully remove the intestine.

10. A large mass of muscle remains. This is composed of the muscles that bend (flex) the abdomen. How do these flexor and extensor muscles compare in size? Why the difference?

11. Draw the point of a knife blade or dissecting needle along the middle line of this muscle, at the bottom of the groove in which the intestine lay. After a thin layer has been cut through, the whole muscle may be easily separated into two rolls the whole length of the abdomen. Roll these carefully aside, pushing equally right and left; otherwise the nerve cord may be injured. Find in the middle line of the floor of the abdomen a slender white **nerve cord**, with enlargements at intervals. How many of these enlargements, **ganglions**, are there in the abdomen? What relation do the ganglions have to the segments? Observe the branches, **nerves**, given off to the muscles on each side. Trace the nerve cord forward to the thorax, where it disappears in the hard framework of the floor of the thorax. Break away as much of this framework as is necessary to follow the cord to the head. Make out that the cord is double. How many ganglions are there in the thorax? Note the branches extending to the legs and other organs. From the large ganglion back of the gullet trace two branches forward, one on each side of the gullet, till they unite in a large ganglion above the gullet, thus forming the **esophageal collar**. From the ganglion above the gullet trace nerves to the eyes, antennæ, and antennules.

12. Cut open the stomach, wash it out with water, and look on its inner walls for teeth.

13. Below and in front of the stomach, find a pair of pale green bodies. These are the **kidneys** or "green glands." Remove the stomach and study the structure of the kidneys. Find where they open externally.

14. Study the joint in one of the big pinchers. Pick out the muscle from the end of the segment, and find the thin, tough white tendons. Seize these with the forceps and pull alternately, to see how the claw is shut and opened. Which is larger, the muscle that opens the claw, or the one that shuts it? Explain.

15. In what characters is the crayfish like the grasshopper? In what do these animals differ? Make a concise list of these points of likeness and difference.

16. Why should the name **Crustacea** be applied to such animals as the crayfish?

Read *The Crayfish*, Huxley.

Topics for Reports. — The Lobster Industry. Shrimps. Crabs. Hermit Crabs. Sea Spiders. Fiddler Crabs. Cocoanut Crabs.

THE SOW BUG.

Sow bugs are usually to be found under boards and stones, and in other damp places. Get the largest specimens for this study.

1. The first part is the head, or carapace.

2. Find and describe the eyes.

3. What are the peculiarities of the antennæ? How many?

4. The jaws and maxillæ are closely pressed together, forming a short, blunt projection under the head. The tip of this blunt proboscis is usually black. A longitudinal groove shows the line of union of the hinder maxillæ. By pinching the body of a live sow bug, the mouth is sometimes more clearly shown by the exudation of a liquid, as in the case of a grasshopper.

Where is the line of division between the head and thorax? Count the appendages which may be supposed to belong to the head; how many rings do these indicate?

5. The line of division between the thorax and abdomen is indicated by an abrupt change in the size of the segments. How many segments has the thorax? Compare the numbers of segments in thorax and abdomen with those of the crayfish.

6. How many segments are there in the abdomen?

7. How many pairs of legs are there? How many segments has each leg? Do the legs all extend in the same direction?

8. A series of thin, overlapping plates under the abdomen are the gills. In the anterior plates observe the white **air chambers.** Beginning at the foremost of these gills, pick them apart with a needle. Remove them, and with a lens make out their shape and arrangement.

9. Under the thorax of the female there is a series of thin membranes attached near the bases of the legs. These are the

egg covers. The eggs, after being expelled from the body, undergo their development in the space under the thorax inclosed by these egg-covers. Look for specimens carrying eggs in this manner.

10. In what respect are the sow bug and crayfish alike? In what respect do they differ from each other?

The crayfish and sow bug both belong to the **Crustacea**. The class Crustacea is divided into several orders. The order to which the crayfish belongs is the **Decapoda**, or ten-footed; the sow bug belongs to the order **Tetradecapoda**, or fourteen-footed.

CYCLOPS.

Along the sides of aquaria, and sometimes in drinking water, there may be seen minute white animals swimming with a jerky motion. Cyclops has a pear-shaped body, and is just large enough to be seen readily with the naked eye. The females carry two egg masses attached to the sides of the abdomen. With a lens, watch these animals through the side of the aquarium. Place a female cyclops with a few drops of water in a watch crystal, or a piece of glass. Examine under a three-legged lens, or under a low power of the microscope.

1. The foremost division of the body is the **carapace**.
How many segments has the thorax?
2. The **egg sacs** are attached to the first ring of the abdomen.
3. The **eye**; note its color, position, shape, and parts.
4. The **antennæ** and other appendages.
5. How does cyclops swim?

Make a careful drawing of cyclops as seen from above. Cyclops belongs to the subclass **Entomostraca** (water fleas).

CHAPTER VI.

ANNULATA.

FIELD STUDY OF EARTHWORMS.

1. In what kind of places does the fisherman dig for earthworms?

2. Are they more abundant in one kind of soil than another?

3. Look for the coiled excrement, or "castings," at the mouths of the holes. How many holes can you find in any square yard? Find the number in several square yards at different places in a rich meadow or pasture, and compute the number in an acre.

4. Do you find earthworms during the daytime? If so, in what conditions? Hunt for them at night with a lantern. Are they far from their burrows? Do they appear frightened? Do they retreat into their burrows?

5. If a worm is found partly extended from its burrow, seize and try to pull it out. Is it easy to do so? Why not?

6. Carefully dig up a number of earthworms. How deep is the burrow? And what is its course? In what part of the burrow is the earthworm? Does the depth at which the earthworm rests depend on the time of day? The condition of the soil? The weather? Is the worm always the same end up? Is the hole much wider than the worm? Could it turn around in the hole?

7. Do earthworms ever plug up the mouths of their burrows? If so, when and with what material? How is this work done?

8. Do you find evidence of what earthworms eat? Do they eat their food outside or in their burrows? Do they store food? Do they spend much or little time eating?

9. Having quietly approached an earthworm that is out, or partly out, of its burrow, suddenly make a loud noise. Does it

seem to hear? Fire a pistol or cracker; does it notice the noise? Stamp hard on the ground; does this affect the worm?

10. In what month are earthworms most active? When least active? Do earthworms hibernate? How early are they seen in spring? How late in the fall?

11. What enemies has the earthworm? Has it any means of defense? On what does it rely for protection?

12. Do you discover anything to prove that earthworms lay eggs? If so, when and where does this take place?

LABORATORY STUDY OF EARTHWORMS.

Get a box a foot deep and a foot or two square. Fill it with fine, rich, black soil and press it down firmly, leaving an inch or so of space above the soil. Keep the soil fairly moist. Earthworms may be kept alive through the winter in boxes, or flowerpots of soil, covered with sod and watered occasionally. The soil should be kept cool and moist, but not wet. Put some dead leaves just under the sod, and occasionally place cabbage leaves or lettuce leaves on the sod for them to feed on. The boxes or flowerpots may be kept in a greenhouse or in a cellar. Cover the box with a large plate of glass. It is well also to have glass windows at the sides and bottom.

1. Place two dozen live earthworms on the soil. Watch them as they burrow into the soil. Do the worms soon become settled, or are they restless? How soon do they reappear at the surface?

2. Test the worms with various kinds of food, meat, both lean and fat, bits of cabbage, celery, onion, turnip, apple, etc. Which do they prefer? Do they show evidence of a sense of taste? Of a sense of smell? Do they eat on the surface or in their burrows? Do they eat the material at once or keep it for a time? Do they eat little or much? Do they exercise choice in selecting bits of food according to their size or shape? When do they eat? Is the process slow or rapid? How is the eating done?

3. Place an earthworm in a glass tube with good black soil, and watch it from day to day.

4. Try the effect of sound on earthworms, being careful that they do not get vibrations that affect the sense of touch during the experiments.

5. Try the effects of light, being careful not to apply heat at the same time. Place the worm in a glass tube, and let the light fall upon one part at a time, covering the rest of the tube with a cylinder of black paper. Try also the effect of heat without light.

6. Repeat any experiments given under "Field Study" that may profitably be reviewed.

7. What is the appearance of the surface of the soil as a result of the work of earthworms? What effect do earthworms produce in the condition of the soil?

STUDY OF A LIVE EARTHWORM.

1. Place a live, active earthworm on a large sheet of paper and watch its behavior. Does it move with the same end always foremost? Touch the end that is foremost to see if it will reverse its motion. What changes take place in its body during locomotion? Can you explain how it progresses?

2. Take the earthworm in the fingers of one hand and draw it over a finger of the other hand to feel the bristles; of what use are they? Can you learn how they are arranged? Do they point more toward one end of the body than the other? Place the worm on glass; can it crawl as well as on paper? Why should the condition of the surface affect the worm's locomotion?

3. Touch various parts of the body to learn the degree of sensitiveness of different parts. sensitive

4. Turn the worm over on its back; does it remain in this position?

5. Take hold of the posterior end of the worm and drag it backward along the paper; listen for any sound thus produced. How explain this result?

6. Rap sharply on the table; does this affect the worm?

7. Place the worm on a wet surface, and after a while on a dry

surface; does it appear equally comfortable in both conditions? Try also the effect of heat and cold, dust, mud, water, etc.

8. Observe along the middle of the back a blood tube; watch its pulsations. Can you discover any other evidences of circulation of blood?

EXTERNAL FEATURES OF THE EARTHWORM.

1. The end that usually goes foremost is the **anterior** end; the other end is the **posterior** end. Are the two ends of the same color? The surface on which the earthworm ordinarily rests is the **ventral** surface; the surface usually uppermost is the **dorsal** surface. The earthworm has **right** and **left** sides, that correspond to each other; such an animal is **bilaterally symmetrical**.

2. The earthworm is segmented, or marked off into rings called segments. How many segments has your specimen? Are the segments all equal in width?

3. About one fourth or one fifth of the length from the head observe a place where the segments are less distinct, often enlarged and with a different color. This is the **girdle**, or clitellum. How many segments does it occupy? How many segments are anterior to it?

4. Is the worm exactly cylindrical, that is, is the cross section a circle? no

5. At the anterior end find the mouth. Overhanging it is a sort of upper lip called the **prostomium**. At the posterior end find the anus. Is it circular?

6. Find the rows of bristles on the sides and ventral surface. How many rows are there and how many bristles in a segment?

7. On the ventral surface of about the fourteenth segment are the rather distinct openings of the **oviducts**, and on the fifteenth the openings of the sperm ducts. Between the ninth and tenth segments are the openings of a pair of sperm receptacles, and another pair open between the tenth and eleventh segments. The positions of these openings vary in different kinds of earthworms, and they are not always easily discovered.

DISSECTION OF THE EARTHWORM.

Material: dissecting pan, forceps, scissors that cut well at the point, dissecting needles, two dozen pins. Ribbon pins are best for this work. Dissect under an inch of water and renew if it becomes turbid.

1. Lay the specimen lengthwise on the board, stretch it, and pin firmly at each end, slanting the head of the pin away from the worm. Cut through the skin of the back near the posterior end, and continue the cut forward a little to one side of the middle line. With the forceps lift the edge of the cut and run the dissecting needle along under it to cut the partitions that hold the body wall down. Turn the edges of the body wall out and pin them down, slanting the pins at an angle of about thirty degrees so they will be out of the way.

2. As soon as the edges of the cut are separated the **intestine** is seen. It is cylindrical, nearly filling the body cavity. It is usually dark-colored from its contents.

3. Along the top of the intestine is the **dorsal blood tube.**

4. Observe now more closely the **partitions** which extend from the intestine to the body wall between adjacent segments. Compare the positions of the partitions with the external markings and bristles. Are there as many segments as indicated by the external appearance?

5. Continue the cut to the anterior end, being careful not to cut into the intestine, especially in the part anterior to the girdle. Pin well out, and free the intestine by drawing the dissecting needle along its sides to cut the partitions.

6. In the region of the tenth segment are several pairs of white bodies, the sperm sacs.

7. Alternating with these are several red masses. They are the **aortic arches**, which spring from the dorsal blood tube and arch around on each side to join the ventral blood tube beneath the digestive tube. In some earthworms each aortic arch has several enlargements, making it resemble a necklace. The enlargements

are sometimes called "hearts." In a recently killed specimen they may be seen pulsating.

8. In the first six segments is a wide portion of the digestive tube, the **pharynx**. It has threads of muscle connecting it with the body wall. The pharynx is used as a proboscis, being protruded from the mouth and everted.

9. The pharynx narrows behind into the **gullet**. This extends through several segments, but is hidden by the sperm sacs and the aortic arches. Clear these away.

10. In removing the sperm sacs there may be seen in the ninth and tenth segments two pairs of small, white, spherical bodies, the sperm receptacles. The still smaller ovaries may be found in the thirteenth segment.

11. Back of the spermaries are two enlargements of the digestive tube. The first is the **crop** and the second the **gizzard**.

12. From the gizzard to the posterior end of the body extends the **intestine**. Is it uniform in diameter? If not, where is it wider and where narrower?

13. Cautiously dissect away the intestine. Under it is the **ventral blood tube**. From it as well as from the other principal blood tubes there are smaller branches to supply all the tissues.

14. On the very floor of the body cavity, in the middle line, is the **nerve cord**, resembling a white thread. Trace it from behind forward. In each segment is an enlargement, or **ganglion**. From the ganglions proceed branches to supply the surrounding organs with nerve fibers.

15. Under the anterior end of the pharynx the nerve cord separates into two parts, one passing up on each side to enlarge into a ganglion. These two ganglions are the **cerebral ganglions**, or **brain**, and the ring of nerve cord around the pharynx is the **nerve ring** or **nerve collar**.

16. Attached to the ventral body wall, on each side of the digestive tube, are many small, threadlike, coiled bodies. Examination with a lens shows a pair of these in each segment. They are the **kidneys** or **nephridia**. Each is a tube thrown into loops

The kidneys open to the outside usually between the inner and outer rows of bristles, but sometimes above the lateral row of bristles. And each tube kidney begins as a funnel, which is in the segment in front of the one in which the loops of the kidney are found.

17. The outer layer of the skin is thin and easily peels off. This is the **cuticle**, and is noticeable on account of its pearly luster. The bulk of the body wall is composed of two layers of muscles, the outer of circular and the inner of longitudinal fibers, by means of which the worm moves.

18. In a freshly opened earthworm mount a drop of the milky liquid found in the body cavity and examine it under a one-sixth objective. The corpuscles should be distinctly seen.

CROSS SECTION OF AN EARTHWORM (MICROSCOPIC).

1. Examine cross sections under the microscope, with a low power, one-half or two-thirds inch objective. The body wall may be seen to consist of several layers. The intestine has an extension, the **typhlosole**, from its dorsal wall, occupying considerable of the space within, and adding much to the inner surface of the intestine.

2. Examine with a higher power, one-fourth or one-sixth inch objective. There are five layers of the body wall: (*a*) the thin **cuticle**; (*b*) a thicker layer of skin, the **hypodermis**, or **epidermis**, which produces the mucus which coats the outside of the worm; (*c*) the layer of **circular muscle fibers**; (*d*) a thicker layer of **longitudinal muscle fibers**; (*e*) a very thin layer of **peritoneal epithelium.**

3. The dorsal blood tube lies embedded in cells on the dorsal wall of the intestine. Under the intestine is the ventral blood tube. Still lower is the nerve cord, or ganglion, as the section may strike.

Read *The Formation of Vegetable Mold through the Action of Earthworms*, Darwin; or the chapters on the earthworm in *General Biology*, Sedgwick and Wilson.

Topics for Reports. — Varieties of Earthworms. Marine Worms. Leeches.

CHAPTER VII.

MOLLUSCA.

FIELD STUDY OF FRESH-WATER CLAM.

LOOK for clams in the shallow water of creeks and lakes. Note the natural position. How much of the shell is embedded? Is the shell open or shut? Can you see any openings by means of which the clam communicates with the water? Touch the clam and note any changes that take place. Quickly pull up the clam and note the extended foot. Watch clams to see if they move. Do they move with the same end always foremost? How does the foot point with reference to the direction of locomotion? Does a clam make a track? Can you tell by the track in which direction the clam traveled? Does the direction of travel have any relation to the current of the stream? Why do clams travel? If possible, make a series of observations to find out the rate of locomotion. Where are clams more abundant, on sandy or on muddy bottoms? How many kinds do you find? Do different kinds show preference as to soil? Has the color of clams any relation to the surroundings? Do you find any evidence that clams have enemies? Of what kinds? How are clams protected from enemies? What conditions are unfavorable to clams? Do they prefer deep or shallow water? Do they occur singly or in groups? Do different kinds occupy the same region?

AQUARIUM STUDY OF A LIVE CLAM.

If a good aquarium is not obtainable, a battery jar, a tub, or a large pail will serve. Put in three inches of sand and add enough water to stand three inches above the sand. Let this stand over night to allow the water to become clear.

Position of the Clam. — Drop several clams into the water and note carefully the place and position of each. Watch them as closely as possible to see if they change their place or position, and if so, learn how this is done.

Locomotion. — Watch clams that have established themselves in their natural position, to find out how they travel. Do they leave a track? If so, of what sort is it? Is the motion slow or rapid? Is it at a uniform rate, or irregular? Quickly pull up a clam that is moving and note the projecting foot. Place a clam close to the side of a glass aquarium; the foot may be protruded so close to the glass as to be seen. Why do clams travel? Can a clam crawl on a hard surface?

Water Currents. — Note that a clam, when established in a natural position and left undisturbed, has the shell slightly open. Near the upper edge of the more exposed end look for two elliptical holes; these are the **siphons**. Watch to see if there is any evidence of currents through these holes. Reduce the amount of water so that it is about half an inch deep over the siphons of a large clam. Look closely at the surface of the water over the siphons for evidence of water currents. Take a slender glass tube, dip one end in ink, place a finger over the upper end of the tube and lift out a little ink. Carefully introduce a drop of this above the siphon opening. The currents may also be revealed by a little mud, but care should be taken not to drop coarse mud or sand on the siphons. What happens when the margins of the siphons are touched? Pull up a clam that is in "full blast," watching closely the siphons. Describe what you observe.

Senses of the Clam. — Test in various ways the senses of the clam. Touch it lightly and heavily; jar the floor near the aquarium. Throw strong light (without heat) upon it. Try heat without light. Test for all the senses you think a clam may possess.

Protection of the Clam. — Note again the changes that take place when an active clam is taken from the water. Now try to open the shell with the hands alone. Why does the clam have such a

hard covering and the ability to shut it so tightly and remain shut so long?

EXTERNAL FEATURES OF THE CLAM SHELL.

If a live clam is used, place it on a plate, or in the dissecting pan.

1. Notice the two parts of the shell, — the **valves.**

2. The edge along which the shell opens is the **ventral margin.**

3. The edge by which the two valves join each other is the **dorsal margin**, or **hinge margin.**

4. The concentric lines parallel to the ventral margin are the **lines of growth.**

5. The raised point around which these lines center is the **beak**, or **umbo.** The umboes are nearer the front, or anterior, end of the clam.

6. Toward the posterior end, back of the umboes, between the valves, and uniting them, is the **hinge ligament.**

7. Hold the closed shell with the hinge margin uppermost, the hinge ligament nearer, and the umboes pointing away from you.

The end pointing from you is the **anterior** end.

The end pointing toward you is the **posterior** end.

The upper edge is the **dorsal** margin.

The lower edge is the **ventral** margin.

The half-shell to your right is the **right** valve.

The half-shell to your left is the **left** valve.

Fix these relations firmly in mind.

8. Make a drawing of the clam as seen from the left side, naming all the parts.

9. Observe the color, the degree of cleanness, and general condition of the different parts of the shell, and consider the relations between these facts and the position of the clam when first found.

DISSECTION OF THE CLAM.

How to open a Clam. — It is difficult for beginners to open clams without mutilating the soft parts. It is better to have them opened by the teacher. If any student is following these direc-

tions without the aid of a teacher, he will find directions for opening lams, without using hot water, in the *Suggestions to the Teacher of Zoölogy*, in a separate pamphlet.

Put the live clam for a few minutes into water as warm as the hand can well bear. This causes the muscles to relax, so that the shell can be readily opened. Pry apart the two valves, and insert a half-inch block to keep them from shutting.

1. Observe a soft white membrane, the **mantle**, adhering to the inner surface of the shell. Look in at the posterior end for the two siphon openings. Now hold the clam in the left hand, with the left valve up and the ventral margin toward you. Insert the chisel-like handle or the blade of a scalpel between the mantle and the left valve, and gently separate them by sliding the scalpel handle along the inner surface of the shell. In this way proceed backward, around the posterior end of the shell, then forward along the dorsal margin. Back of and below the hinge is a large white muscle, which extends directly across from valve to valve. Cut this off close to the left valve if it is not already severed. In like manner loosen the mantle at the anterior end, and find another muscle connecting the two valves near the anterior dorsal margin. Sever as before, close to the left valve, and loosen the mantle completely from the left valve.

2. Press the shell shut; now release the pressure. What makes the shell spring open? Repeat the closing and releasing until you have a satisfactory explanation of the method of opening. Be on the lookout later for the means by which the clam shuts its shell. Break off the left valve by bending it forth and back, twisting it off if necessary.

3. Lay the clam in the dissecting pan and cover it with water. Renew the water as often as it becomes turbid. To keep the clam level use the left valve, hollow side down.

Observe that the left mantle lobe now covers the body, and that the right lobe lines the right valve. Notice the thicker margin of the mantle. Pinch this thick edge; if it has not already shortened as much as possible it may draw up slightly. Observe a thin,

dark-colored membrane bordering the edge of the shell. This is the periostracum, an extension of the outer covering of the shell. Scrape off some of it to see its relation to the limy shell. Carefully study the relations of the periostracum to the mantle. Pinch the edge of the right mantle lobe, and observe the effect on this free border. Trace the right and left mantle lobes to their points of union before and behind.

4. Examine the thick, dark-colored, hinder edge of the mantle lobes, and see how by their manner of meeting they form the two short tubes, the **siphons**. Prove the great sensitiveness of the margins of these siphon tubes. Are the margins of the two openings alike?

5. Examine the ends of the **anterior** and **posterior adductor muscles** where they were cut off in opening the shell; scrape away any part of these muscles that may remain attached to the left valve, and note the marks or **muscle scars** which are shown.

6. Turn the mantle lobe back as far as it will go, and observe the soft central **body**; its tough lower border is the **foot**; prick it with the dissecting needle, and observe what follows.

7. Along each side of the body and extending back of it are two thin membranes, the **gills**, showing vertical parallel markings. Study closely the relations of the gills to each other, to the body, and to the mantle.

8. With a knife scrape off a little of the surface of the gill and examine under the microscope to see the vibratory motion of the hairlike projections, or **cilia**, borne on the cells thus obtained.

9. In front of the gills, on each side of the body, are two thin triangular flaps, much smaller than the gills, the **labial palps**.

10. Raise the hind border of the left mantle lobe, and observe that the gill next to the body unites with the corresponding gill of the other side, thus forming a separate channel above the gills, from which the upper siphon leads, while the lower siphon leads to the lower cavity, outside of and below the gills.

11. With the thumb and all the fingers of the left hand seize the left lobe of the mantle and pull it toward the ventral margin,

thus drawing the body away from the dorsal margin. Just under the hinge a pale organ may be seen, pulsating every few seconds; this is the **heart**.

12. Holding the mantle stretched, again examine the upper siphonal opening; probe to see how it extends forward above the united hinder portion of the gills. In the upper part of this cavity find a tube running back over the posterior adductor muscle, and ending in a conical elevation; this tube is the intestine and the opening at its end is the anus; hence the siphon leading from this cavity is called the **anal siphon**; the lower siphon, which conducts water to the gills and mouth, is called the branchial siphon or gill **siphon**. Examine the gills from above, and examine their dorsal margins; observe that the two outer walls of each gill are a short distance apart at this edge, while below these walls unite so that if the gill be cut across, these walls, as seen at the cut, are like the letter ***V***. These diverging walls are connected by cross partitions, thus forming a series of compartments within the gill, whereas if these partitions were absent, each gill would be a deep, narrow, undivided trough. The lateral walls of the gills are sievelike, and the surface of the gill and the edges of the holes are covered with cilia. The vibrations of these cilia drive the water which is around the gill through these holes into the cavities within the gill; the water from each compartment of the gill passes up into the chamber leading to the anal siphon.

13. Beginning at the upper edge of the anal siphon, in the middle line, cut carefully forward just above the intestine as far as the umbo. This lays bare the cavity in which the heart lies, the **pericardial cavity**. Carefully cut away the thin covering of this cavity and make out the following parts of the heart: —

a. The large yellowish **ventricle** in the anterior part of the cavity; time its pulsations; observe that the intestine runs directly through the ventricle, though it has no communication with it. An artery runs forward from the ventricle along the upper surface of the intestine; another artery runs from the ventricle backward under the intestine. Again pull the mantle ventralward to show *b*.

b. A thin sac, triangular as seen from the side, with its apex joining the ventricle, and its base attached just above the upper edge of the gills; this is the left **auricle**. Each auricle receives the blood from the gills of the corresponding side.

14. Just in front of the posterior adductor muscle are the dark **kidneys**.

15. Above the kidney, and in front of the posterior adductor, is a small muscle, which extends backward from the side of the body to join the valve near the posterior adductor. This muscle pulls the foot upward and backward, hence is called the **posterior retractor muscle.**

16. Below and a little back of the anterior adductor muscle, find the **protractor muscle**, which pulls the body and foot forward.

17. Just above and back of the anterior adductor is the **anterior retractor muscle**, which pulls the foot and body up and backward.

18. To find the **mouth**, hold the clam, anterior end uppermost, still attached to the right valve; press down the point of the foot, and find the mouth opening posterior to the anterior adductor; observe that the two outer palps unite above the mouth, and the two inner palps unite below the mouth. Back of the anterior adductor a dark-colored mass may be seen within the body; this is the **digestive gland**, which surrounds the stomach. The intestine has several coils in the body before emerging on the dorsal surface a short distance in front of the heart. The intestine can be traced much better in an alcoholic specimen.

19. Beginning at the posterior adductor, cut away all the free flap of the left mantle lobe, following the upper edge of the gills (being careful not to cut away the labial palps) to the upper edge of the anterior adductor. Make a drawing of all the parts above named, as they lie in the right valve.

20. Remove all the remaining soft parts except the adductor muscles. Since the chief characteristic of muscle is its ability to shorten, it should now be clear how the clam shuts its shell. Turn back to No. 2 of these directions and consider the relations of the mechanisms for opening and shutting. What actions take place

during the closing? What actions during opening? Thoroughly clean the inside of the shell, and keep it for further study.

DEVELOPMENT OF THE CLAM.

Occasionally a clam may be found with the outer gills greatly thickened. Cut into such a gill and remove some of the contents. Place a little of the material on a slide and spread it out in a drop of water. Examine with a low power of the microscope. The parts of the young clams should be seen. How does the shape of the shell compare with that of the adult?

THE NERVOUS SYSTEM OF THE CLAM.

This dissection requires the utmost care and patience. Take a clam that has been hardened in alcohol, or by boiling. Dissect under water; rinse the specimen often.

1. Immediately under the posterior adductor muscle find a double yellowish body; this is composed of the two **visceral ganglions**; dissect away the thin membrane covering them.

2. From these ganglions trace nerves backward to the gills and to the posterior borders of the mantle lobes; trace also two nerves forward, carefully dissecting away the soft parts that cover them anteriorly, and trace them to the sides of the mouth where they join 3.

3. The **cerebral ganglions**; these lie near the surface at the bases of the **labial palps**. Trace a small nerve which connects the two cerebral ganglions over the mouth.

4. From each cerebral ganglion trace nerves backward and downward to 5.

5. A pair of orange-colored **pedal ganglions**, lying together deeply embedded between the foot and the body.

In the alcoholic specimen the stomach and intestine may be traced. Cross sections of alcoholic specimens may be made with a razor, which show admirably the relations of the different parts of the clam.

THE INSIDE OF THE CLAM SHELL.

1. Observe the color of the lining layer. Is it uniform? How would you describe the surface finish.

2. The **hinge teeth**. These are of two sorts: (1) the **cardinal teeth**, blunt, toothlike projections near the umbo; (2) the **lateral teeth**, long, ridgelike projections below the hinge ligament. Note how many of each of these kinds there are in each valve. How do they fit into each other? What is their use? Do you find them in all clam shells?

3. The **muscle scars**: (1) the **anterior adductor muscle scar**, near the anterior dorsal margin; (2) the **posterior adductor muscle scar**, near the posterior dorsal margin; (3) the **anterior retractor muscle scar**, just above and back of the anterior adductor scar, not very distinct; (4) the **posterior retractor muscle scar**, just above and in front of the posterior adductor scar; (5) the **protractor muscle scar**, just below and back of the anterior adductor scar; (6) the **mantle line**, running parallel to the ventral margin, from the anterior adductor to the posterior adductor scar.

4. The movements of the muscle scars. When the clam was smaller than it now is, where were the adductor muscle scars? Can you see any traces of the positions of these muscles at an earlier stage of life? Is there an evidence of growth over any part of the muscle scars that now show? Does the mantle line shift its position with growth?

5. The **ligament**. Examine the hinge ligament where it was broken off. Has it a definite structure? What is its chief characteristic?

6. Take an empty shell with the vaives still hinged together; cut and fit into this a piece of paper showing the shape of the whole mantle.

7. Make a plaster of Paris cast of the inside of a whole shell.

8. Make a drawing of the inside of the right valve, labeling all the features above noted.

Take a large flat shell and label (with ink) both the external

and the internal features; it may be found convenient to label part of the features in one valve and part in the other.

Structure of the Clam Shell. — For this work get the thickest and heaviest shells, at least one valve for each member of the class. Weigh them and then roast them by laying them on an old shovel or layer of sheet iron, and placing them on the coals in a stove or furnace. After roasting handle them carefully so as to keep them entire. Weigh them again after roasting and compare with the former weight.

Hold a roasted valve by the dorsal margin in the left hand, with the inside of the valve toward you. With the fingers of the right hand supporting the outside of the valve, press with the thumb on the ventral border of the valve, outside of the mantle line. The shell should separate into two parts, the inner beginning very thin at the mantle line and becoming thicker toward the umbo; the outer portion extending the whole width of the valve, but becoming thicker from the umbo to the mantle line and thinner again from this line to the ventral margin. It will be seen that the plane of division is the plane along which the mantle line has traveled during the growth of the shell. Break a burnt shell across from the umbo to the ventral margin, and make a drawing of the edge thus exposed, showing the arrangement of these sets of layers.

Composition of the Clam Shell. — Put pieces of the burnt shell into dilute hydrochloric acid. The acid decomposes the limy compound, setting free carbon dioxid. If a fresh shell is placed in acid, the mineral matter will be slowly dissolved, leaving the flexible animal matter, which is called **conchiolin**. The hinge ligament is nearly pure conchiolon, being simply a part of the shell in which no limy matter has been deposited. When the shell is burned the animal matter is burned. The remainder after roasting is of about the same composition as lime. Put into acid a piece of the ligament. Does it contain lime? Place an entire valve of a thin-shelled clam in acid for forty-eight hours; what remains? Are shells ever found in rocks?

Topics for Reports. — The Oyster Industry. The Pearl Fisheries. Pearls from Fresh-water Clams. Kitchen Middens. Clambakes. Wampum. Tridacna. Mother-of-pearl. Pearl Button Factories. The Chambered Nautilus. The Paper Nautilus. The Giant Squid. The Octopus. Snails as Food.

THE POND SNAIL.

A dipper with a perforated bottom, attached to a wooden handle, will be found convenient in scooping up the sand and mud from the bottoms of ditches and streams; the dirt being washed out, the shells and other objects will be left behind. Get a number of live snails, and keep them in a fruit jar.

1. The broad disk on which the snail creeps is the **foot.**

2. The "horns" are the feelers, or **tentacles**; touch them; what would seem to be their use?

3. The dark spots at the bases of the tentacles are the **eyes**; are they borne on a stalk in any common snails?

4. Watch the snail crawling on the glass; near the front of the foot the **mouth** may be seen; observe its opening and shutting as the snail gathers food from the surface of the glass. Do snails clean the glass or foul it? Most snails have a ribbonlike tongue, fastened at each end, and covered with teeth; as this tongue is applied to an object, and drawn rapidly back and forth, it acts like a rasp.

5. Watch the snails, to see if any of them come to the surface to get air; how is this done?

6. Collect also land snails and river snails. Keep them and watch them to learn their structure and habits.

THE SNAIL SHELL.

1. The pointed end is the **apex**.
2. The opening at the large end is the **aperture.**
3. The outer edge of the aperture is the **lip.**
4. The lines parallel to the lip are the **lines of growth.**
5. The spiral groove on the outside is the **suture.**

6. The turns of the shell between the groove are the **whorls**.

7. The whorls, taken together, make the **spire**.

8. The lid closing the aperture is the **operculum**; is this present in all the snails you find?

9. Lay the snail shell beside a common screw; if the whorls turn like the threads of the screw, it is a **right-hand**, or **dextral**, **shell**, if they turn the other way, it is a **left-hand**, or **sinistral**, **shell**.

10. Make a drawing, naming all the parts, of the snail shell with the aperture toward you; with the aperture away from you; with the apex toward you.

Read *The Chambered Nautilus*, Holmes.

CHAPTER VIII.

PISCES.

FIELD STUDY OF FISHES.

Difficulties. — In order to study fishes in their own homes with any degree of success, the student should know what are some of the main difficulties. First, a difficulty that is found in studying any wild animals, their shyness. The student must learn to approach them carefully. Second, the colors of fishes, as of many other animals, is such as to render them very hard to see. Third, the difficulty in seeing them is increased by the refraction of light leaving the water to enter the air, and also by the reflection of light from the surface, which greatly interferes with seeing what is below. This is especially noticeable in trying to see fishes from a boat, in which case the angle is quite oblique. Having in mind these difficulties and the determination to overcome them so far as possible, let us proceed to study the fishes in their homes.

Frightening Fishes. — When a fish darts away at your approach, endeavor to learn by what sense he first became aware of your presence. Was it by sight? If so, what can you do to overcome the trouble? Is it the color of your clothing, or of your boat? Is any given color, or group of colors, preferred for fishing boats? Which will frighten more, oars or a paddle? Should the paddle be lifted from the water, or used wholly in the water by making the recover stroke with the edge of the blade cutting thru the water? What part does the sunlight play in the use of oar or paddle? Does quickness of motion make any difference, the range of motion being the same? In using an anchor, which is better, a rope or a chain? Which is to be preferred, a wooden or a metal boat? Do fishes hear one who talks in a boat? Do sounds made by hitting the

boat, as with the heel, communicate with the water? Is it well to have bright metal, such as nickel or silver, on fishing rods?

The Water Glass. — The difficulties of seeing into water may, to a considerable extent, be overcome by the use of a water glass. This is a box or cylinder with a glass bottom. When the glass bottom is pushed down into the water, the face over the open end shuts out most of the light from above, thus getting rid of the confusion from reflection. It is possible to make such a glass as part of the boat, so one can view what is under the boat.

Food of Fishes. — Find what the fish you are studying prefers to eat. If you are fishing, examine the stomach of the first fish you catch to see what it has been eating. The wise fisherman will do his best to cater to the taste of the fish he would catch. Why does the fly-fisher drag the fly on the water, or make it dance about? Find the time of day at which a fish prefers to eat. Does this vary with any discoverable conditions? Do fishes eat during the night? What do the various artificial baits imitate?

Hiding Places. — What sort of places do fish hide in? Do they hide to escape enemies, or that they may catch unsuspecting prey that passes by their lurking place? In what situations does the fisherman look for different kinds of fishes?

Sociability. — What fishes live a solitary life? What kinds go in schools? What advantages in community life? What disadvantages? Does a school of fish scatter when frightened? Do they come together again soon?

Position in a Current. — When in a current do fishes maintain any fixed relation to the current, that is, do they rest crosswise, or lengthwise, in the stream? If lengthwise, is the head up or down stream? Why this position?

Egg Laying. — At what season does the fish you are studying lay its eggs? Are they usually deposited in the same surroundings? How long time is taken in depositing them? Are they guarded? What animals may destroy them? What conditions are favorable

or unfavorable to their development? If possible, learn the rate of growth of fish.

Fish in Winter. — Do fishes migrate? Are most fishes to be found in the same place, winter and summer? Are they equally active at different seasons?

AQUARIUM STUDY OF FISHES.

Respiratory Movements. — Watch minnows or goldfish in an aquarium. Note the movements of the mouth and the gill covers. In what order do these movements proceed? Watch closely to see if there is any water current in connection with these movements. If there is no floating matter by which to get evidence of a current, introduce a drop of ink near the fish's head and thus determine the direction of the current.

Mode of Swimming. — How does the fish swim? Watch especially the slow movements, during which the facts can be more readily learned. What is the main propelling power? How is the course guided? How is the shape adapted for movement in the water?

Uses of the Fins. — Take a light rubber band and pass it round the fish, holding down the various fins in successive experiments. Watch the resulting movements and conditions of the fish.

How a Fish Floats. — Does a fish make effort to maintain its place in water? Does it make any apparent effort in rising or sinking? Do any fishes habitually remain on the bottom? Do any stay at the surface? Is there any difference in their structure or habits that fits each for its place?

Comparison of a Minnow and a Darter. — These two forms are to be found in most creeks. In using a minnow seine, be careful to "keep the lead line down" and you will be much more likely to get darters. These are small fishes, with double-cone-shaped bodies. They habitually rest on the bottom. Watch carefully their movements. What takes place when they cease to make active effort? Do they swim in the same way as the minnows? Open a minnow and also a darter to see if there is any essential difference

in the structure of the two. Why should the darters have this habit of staying on the bottom?

Senses of Fishes. — Watch the movements of the eyes of a fish. What range of movement have they? Do the eyes move simultaneously? Does a fish see any better than you do? Devise means of testing the sense of hearing without affecting the other senses. Test the different senses in various ways. On which senses does the fish most rely for safety?

Food and Mode of Eating. — Offer a fish various kinds of food and find what it likes best. How does it take its food? What relation has the shape or size of the mouth to the kind of food taken? Does a fish eat much, or little, relatively? In feeding fishes take care not to give too much at one time, for fear of fouling the water. Do fishes suffer from overeating?

Sleep. — Do fishes sleep? Have they any special resting place or resting position?

EXTERNAL FEATURES OF A FISH.

For this work, and the dissection that follows, the perch is preferable for inland students, though the bass, croppie, or sunfish serves very well. On the seacoast the cunner or the sea perch is more accessible.

Lay the fish on a sheet of thick paper, on a plate, or in the dissecting pan.

1. Notice the shape of the fish as a whole; how is it adapted for motion through the water? Hold the fish with the back uppermost and the head directly away from you; instead of speaking of the front and hind ends, it is better to call them the **anterior** and **posterior ends**. The upper surface, or back, is the **dorsal surface**, and the lower the **ventral surface**. The **right** and **left** sides are counterparts of each other; that is, the fish is **bilaterally symmetrical**.

The perch is flattened from side to side, and is therefore said to be **compressed**. A fish is properly described as "flat" only when flattened on the dorsal and ventral surfaces, or **depressed**, as in the case of the rays.

In the following directions, relative and not absolute measurements are intended. Instead of using a foot rule, take a strip of paper and mark the entire length, head, depth, etc., either by pencil or by folding. Compare these so as to be able to say whether the head is one third, one fourth, or what part, of the length of the body.

Close the mouth of the fish, and measure from the foremost point of the head, the tip of the **snout**, to the front edge, the **base**, of the tail fin; this is the **length** of the fish. Measure from the tip of the snout to the hinder point of the hard part of the flap which covers the side of the head; this is the length of the **head**. How many times is the length of the head contained in the length of the fish? Measure from above downward at the deepest part; this is the **depth** of the fish. How many times is it contained in the length? Compare the **width** and the depth of the fish.

2. The fins on the back are the **dorsal fins**; spread them out to their fullest extent, and study them thoroughly; their framework consists of **fin rays**, some of them **spinous rays**, or **spines** (unjointed, or **inarticulated**), others **soft rays** (jointed, or **articulated**). Study carefully one of the soft rays, using a lens; spread the fin and hold it between you and the light to see the joints, which appear as fine cross lines on the soft rays; count each kind of rays; observe the membrane connecting the rays. This membrane is double; the fin is really a fold of the skin, with supporting parts within the fold.

Measure along the base of each fin; this is the **length** of the fin; extend the fin fully, and measure the length of its longest ray; this is the **hight** of the fin. Compare the length and the hight of the fin. In some fishes the dorsal fin is single; in others it is divided, forming two or more dorsal fins.

The tail fin is the **caudal fin**; is it symmetrical? The fin in front of and below the caudal is the **anal**; compare this fin with the dorsal. The fins above named, being in the middle line, are called **median, or vertical, fins**.

The remaining fins are called **paired fins**; the pair back of the head are the **pectoral fins**, and are considered as representing the fore limbs of the higher animals; the lower pair (usually farther back) are the **pelvic fins**, representing the hind limbs of higher animals. Take the pelvic fins between the thumb and finger to feel their bony support; rest the fish on its back, and press the thumb and forefinger of the other hand on the bony structures at the bases of the pectoral fins; move the pelvic fins about to determine, as far as possible by feeling, the relations between the bones supporting the two pairs of fins.

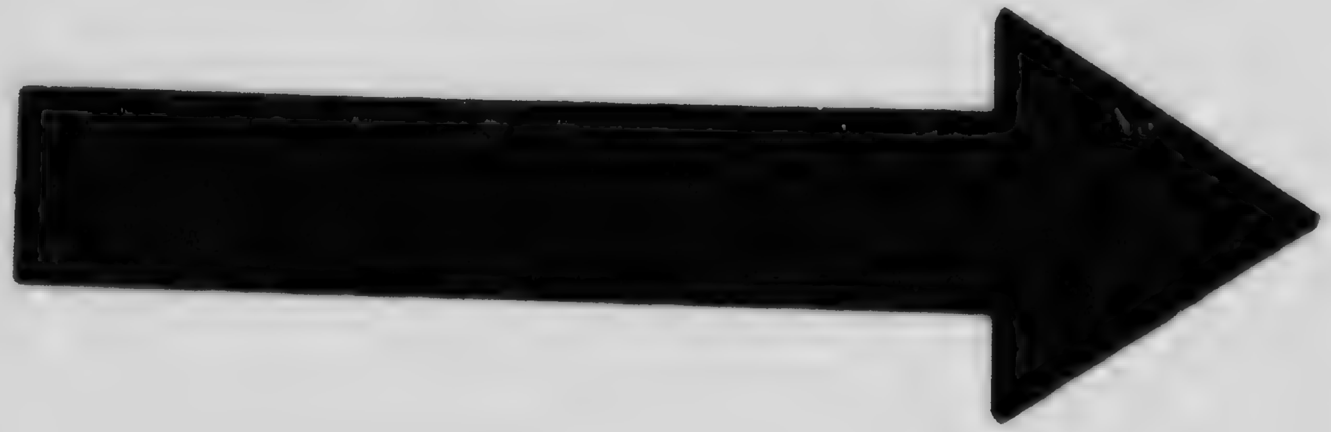
3. Open the mouth of the fish by pulling its lower jaw down as far as possible; the bone which forms the border of each side of the upper lip is the **premaxillary**; note its extension backward on the middle of the snout; observe the fine teeth on it. Observe their size, shape, arrangement, and the direction in which they point. The paddlelike bone back of the premaxillary, outside of the mouth, is the **maxillary**. The bone on each side of the lower jaw is the **dentary**.

Which of the above-named bones bear teeth? Open and shut the mouth repeatedly, watching the movements of these parts, and their relations to each other.

Back of the premaxillary, in the front part of the roof of the mouth, is a patch of teeth, borne on a bone called the **vomer**; extending backward from the vomer, on each side of the roof of the mouth, are rows of teeth on the **palatine bones**.

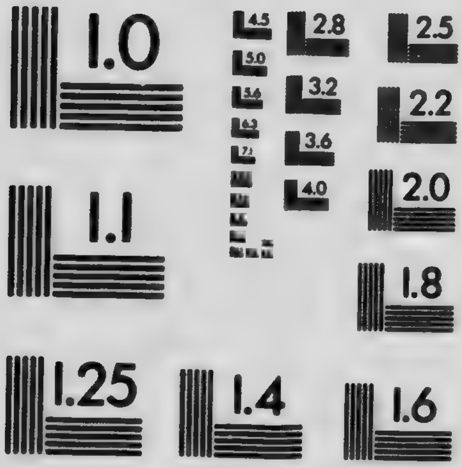
Examine the short **tongue**; feel its surface with the tip of the finger, or scrape it with the head of a pin; examine also the whole of the inside of the mouth, to see if there are more teeth than those mentioned.

4. Note the shape and position of the eyes; with the handle of the forceps press on the eye at various points near its margin, to see its range of motion; watch the roof of the mouth while pressing the eye, also press outward on that part of the roof of the mouth nearest to the eye. Compare the eyes with human eyes. Are eyelids present? Observe a thin bone embedded in the skin



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



immediately in front of the eyes; it is the **anteorbital bone**. This and several smaller bones just under the eye are known as **suborbital bones.**

5. Examine the **nostrils** in front of the eyes. How many are there? Probe them with a bristle tipped with sealing wax, or with the head (never the point) of a small pin; do they open into the mouth? Do any of them communicate with each other?

6. The flap at the side of the head is the gill cover, and the opening back of it is the **gill opening**. The upper, hinder piece of the gill cover is the **opercle**; along its lower posterior border, and rather closely attached to it, is the **subopercle**; in front of the opercle, and below and back of the eye, bordering the part known as the **cheek**, is the **preopercle**. If the margin of this be toothed, it is said to be **serrate**; under the preopercle, and in front of the lower end of the subopercle, is the **interopercle.**

The thin membrane below the gill cover is the **branchiostegal membrane**; the curved bones supporting it are the **branchiostegal rays**; count them. The narrow part of the body between the branchiostegal membranes is the **isthmus**.

7. Raise the gill cover and examine the **gills**; each gill has a central bony **arch**; on the hind and outer border of this arch is a fringe of red **gill filaments**; on the front and inner border of the arch are the teethlike **gill rakers**. Are these alike on all the gills? A red streak along the arch, at the base of the filaments, is made by the blood tubes, which bring the blood to and carry it away from them.

Thrust a finger into the mouth, and depress the tongue. What effect has this on the gills? What effect on the gill rakers? The slits between the gills, which allow communication from the mouth to the gill openings, are the **gill clefts**. How many gills are there? How many gill clefts? After this study of the gills in their natural position, remove the foremost gill, severing it at its upper and lower ends, and note more fully the parts above named, especially the structure and arrangement of the gill filaments and gill rakers; tear away some of the filaments, and find the **groove**

along the posterior, outer border of the bony arch in which run the blood tubes. Look on the inside of the gill cover for a red spot, the **false gill**.

8. Observe the arrangement of the scales. Pull out a scale and study its shape and the radiating and concentric markings. Compare its inner and outer surfaces, its anterior and posterior margins; make a drawing of it, naming its parts; pull out a scale from a black spot; compare that part of its surface which was exposed with the part overlapped by other scales; scrape the portion that was exposed; thrust one point of the forceps under the hind edge of a scale, and watch closely this edge, while slowly raising it, to see that a thin skin covers it and passes on to the scale behind. This thin outer skin is chiefly **epidermis**. In this epidermis lie the black **pigment cells** which make the dark spots. A scale with a smooth hinder border is a **cycloid scale**; if the hinder portion is toothed or spiny, the scale is **ctenoid**.

9. A raised line along the side is the **lateral line**. Remove one of the scales on this line, and find what makes the line. Is the line continuous?

10. Make a drawing of the fish as seen from one side, naming all the parts visible. Describe fully all the parts above noted, including the general color and markings.

Use Jordan's *Manual of the Vertebrates* for finding the names of the fishes of your neighborhood.

DISSECTION OF A FISH.

Dissect on a board covered with paper. A few **carpet tacks** will be needed.

Hold the fish with its back in the pal. of the left hand and the tail toward you. Thrust the point of one blade of the scissors obliquely forward through the body wall just in front of the anus, and continue the cut forward half an inch. Now rest the fish on its back and get hold of the edge of the cut with the forceps; as you cut forward in the middle line lift the edge of the body wall to see that no internal organ is injured. When the pelvic fins

are reached, the body wall is stronger and cannot be cut with the tips of the scissors without danger of straining them; lift with the forceps almost enough to raise the fish; insert nearly the whole length of one blade so as to cut near the joint of the scissors between the pelvic fins. Continue the cut to the narrowest part of the isthmus, where it joins the branchiostegal membranes.

1. Observe that most of the internal organs are in one large cavity, called the **body cavity**. Its silvery lining is the **peritoneum**.

2. Near the anterior end of the opening, about opposite the posterior border of the gills, find a transverse partition, the **false diaphragm**; back of this is the main body cavity; in front of the partition is the pericardial cavity, which contains the heart.

3. Keeping the fish still on its back, turn now to the posterior part of the body cavity. While holding the edge of the body wall, use the scalpel handle to push aside the internal organs. Note how yielding is the membrane on which the internal organs rest. Beyond this membrane is the air bladder. Be careful not to cut into it until directed to do so.

4. Turn the abdominal wall outward and note the projections made by the ventral ends of the ribs. Begin again at the point of beginning of the first cut, just in front of the anus, and, with scissors, cut the right side of the body wall along the ends of the ribs as above noted. Continue the cut as far as the bony pectoral arch, just back of the gill opening. Repeat this cut on the left side. Look again at the false diaphragm and its relations to surrounding organs, as it will probably be torn in following subsequent directions. Now turn the two flaps of the body wall well out and forward, and tack them down so as to hold the fish securely resting on its back.

5. In the front part of the body cavity is a dull pink or brownish mass, the **liver**, lying chiefly on the left side of the fish. Raise the hinder edge of the liver, and observe how closely it fits the organs next to it. Press the liver backward, and observe the **hepatic veins** passing forward from the liver through the thin partition, the false diaphragm, in front.

6. Turn the liver to the right, gently tearing away its threadlike attachments. This uncovers a pinkish sac, the **stomach.** Pass a probe back from the mouth and wide gullet into the stomach to determine its shape and extent. Such a stomach as that of the perch, ending blindly at the posterior end, and with the intestine arising from near its anterior end, is said to be **cecal.** Sometimes the posterior end of the stomach of the perch is found turned in, like an inverted glove finger, occasionally to such an extent as to be seen projecting from the gullet into the mouth. Observe a white thread, the **vagus nerve,** distributed over the side of the stomach.

7. Find a large tube, the **intestine,** arising from one side of the stomach. A short distance from its origin, the intestine has several short, blind branches, the **pyloric ceca.** How many are there and how are they arranged? Make a small hole in the end of one cecum; insert the point of a blowpipe and inflate to show the intestine and ceca.

8. Just beyond the ceca, on the posterior surface of the liver, is a thin-walled sac, of a greenish or yellowish color, the **bile sac.** If it contains bile, press on it to show the course of the bile duct to the intestine. When empty, it often has a wormlike appearance. Snip it open with the scissors, or prick it with a dissecting needle to see the bile.

9. Trace the intestine to the anus, observing that it is held in place by a thin, transparent membrane, the **mesentery**; observe the blood tubes in it; tear this away in following the intestine; near the intestine find a small, deep red body, the **spleen.**

10. In the hinder part of the body cavity of the female is the yellow, or pink, **ovary** (varying greatly in size, according to the season). The two white **spermaries** occupy a corresponding position in the male. In some fishes the ovary is single, in others it is double. If double, the two ovaries unite in one tube, which discharges the eggs, the egg tube, or **oviduct.** Trace the oviduct; has it a separate outlet? Sometimes the eggs in the ovary can be discerned.

11. Back of the oviduct or hinder part of the spermaries is a small, pink (sometimes pale green) sac, the urinary bladder. Look for its external opening back of the anus.

12. Gently separate the parts of the digestive tube, and remove any fat that is in the way. Make a diagrammatic sketch of the digestive organs as seen from the ventral aspect, showing and labeling the stomach, intestine, ceca, and the anal opening.

13. Turn now to the pericardial cavity and examine the heart. The red, angular portion of the heart, which in the natural position of the fish lies lowest and hindmost, is the **ventricle**; the darker, more irregular portion lying (in the natural position) above the ventricle, is the **auricle**; the larger blood cavity back of the auricle, and extending across the body cavity, above the false diaphragm, is the **venous sinus**; in front of the ventricle is the light-colored conical **arterial bulb**. This narrows forward into an artery which gives off branches on both sides, one to each gill. Make a drawing of the heart and arterial bulb. After passing through the gills, the blood tubes unite to form the **dorsal aorta**, which passes backward just underneath the spinal column. From above the gills branches also run forward to the head. Cut away and remove the liver, stomach, intestine, and ovary (or spermaries).

14. In the dorsal part of the body cavity is the air bladder. Carefully scrape away some of the thin peritoneal covering and note the thin, transparent wall of the air bladder itself. Scrape away as much as possible of the peritoneum covering the air bladder, in order to see if there are any blood tubes in the walls of the air bladder. Make a puncture in the center of the air bladder. What is the result? Slit the air bladder along most of its length and explore its extent and relations. Except on its ventral surface it is attached to the inside of the walls of the body cavity.

15. Dorsal to the air bladder, extending along the roof of the body cavity, are slender, dark red bodies, the kidneys. With the forceps tear away the false diaphragm and as much as possible of the air bladder. This should disclose the most distinct part of

the kidney lying anterior to the air bladder and dorsal to the gullet. See if you can trace the kidneys to the urinary bladder.

16. If the mouth and gill covers are not already widely stretched, loosen one or both tacks and set them farther out. Examine the branchiostegal membrane and its supporting rays. Look into the mouth to see the relations between the gills, gill covers, and gullet. Note also the position of the tongue. Cut forward and inward on each side between the gills and the gill covers till the two cuts meet in front of the tongue. Again examine the gills from the front. Pull up the tacks and press the ventral ends of the gills toward the roof of the mouth. Study the action of the joints in the gills. What is the use of the gill rakers?

Observe, where the gills unite above and below, patches of closely set teeth, the **superior** and **inferior pharyngeal teeth.** The bones supporting these teeth, above and below, are the pharyngeal bones. Again depress and raise the lower ends of the gills, observing how the pharyngeal teeth are brought together. What is the probable use of these teeth, and what is the work done by the teeth previously examined?

Remove the gills by cutting the thin membrane back of them, between the isthmus and their ventral ends; above, cut close to the base of the skull.

17. Examine the bones in the posterior border of the gill opening; these are together called the **pectoral arch.** Cut away the flaps of the body wall bearing the fins.

18. Note also the bones supporting the pelvic fins; these are considered as representing the **pelvis.** In the higher fishes the pelvis is fastened to the clavicle; in the lower fishes it is separate from the rest of the skeleton and embedded in the flesh. How is it in the specimen you are studying? Carefully remove the pelvic fins, with the bones which support them; examine and describe them, after scraping away all muscles and other soft tissues.

19. Hold the fish in the left hand, with its back up and its head away from you; insert the point of one blade of the scissors at the base of the caudal fin and cut the skin forward, passing to

the left of the dorsal fin and on to the head. Remove the skin of this side, carefully leaving the white muscles beneath undisturbed; scrape part of the skin clean on the inside; note the arrangement of the scales as seen on each side of the skin; look also for traces of the lateral line on the inside of the skin. Hold the skin up and look through it toward the light, alternately stretching and shortening it, noting especially the lateral line. Roll the skin lengthwise, with the scales outermost, to see how the epidermis passes from one scale to another.

20. Observe the parallel transverse markings on the muscles along the body.

21. Cut and scrape away all the muscle of this side of the body down to the bones, and make out the central backbone, with its bony projections above and below. Bend the dorsal and anal fins from side to side, to show the bones which support these fins and the relation of these fin supporters to the projections of the backbone.

22. Break across the backbone under the center of the second dorsal fin, and remove one piece, or **vertebra**, of the backbone; clear away all muscle and other tissue, and make out the following parts:—

a. The central body, or **centrum**, shaped like an hourglass and hollowed at each end.

b. Two projections extending upward, soon uniting to form one spine, the **neural spine**.

c. The archway formed above the body of the vertebra is the **neural arch**.

d. A similar arrangement below, forming the **hemal arch** and **hemal spine**.

Make a drawing of this vertebra as seen from the side; another as seen from the front.

23. In like manner remove and study a vertebra from a point opposite the center of the first dorsal fin, with the ribs attached to it. What are the differences between these two vertebræ?

24. Thoroughly clean the last vertebra, and study carefully its **relations to the caudal fin.**

25. Observe the white **spinal cord** in the tube formed by the neural arches above the bodies of the vertebræ. This is the nerve tube, or **neural tube**; note also the blood tubes in the corresponding **hemal tube,** below.

THE BRAIN OF THE FISH.

Cut off the head; clear away the muscles at the back of the head; carefully slice off the top of the skull with a strong, sharp knife; with extreme care cut away the roof of the brain cavity; a mass of loose, gray tissue covers the brain, which is of a white or pinkish color; cautiously pick away this loose tissue, using a small syringe, or medicine dropper, to wash away the loosened matter. Make out the following parts of the brain, beginning at the posterior end: —

1. The cut-off end of the spinal cord.

2. The widened part of the spinal cord, where it passes under the hinder part of the brain, is the **spinal bulb.**

3. The hinder, undivided part of the brain is the **cerebellum.**

4. In front of the cerebellum are the two large, rounded **optic lobes,** forming the widest part of the brain.

5. In front of the optic lobes are two oval masses which meet in the middle line; these are the **cerebral hemispheres,** and together they constitute the **cerebrum.**

6. Observe the **olfactory lobes** tapering forward in front of the cerebral hemispheres; from these trace the **olfactory nerves** to the nasal cavities.

Make a drawing of the brain as seen from above, naming all these parts. Cut open one of the optic lobes and note that it is hollow; push the eyes outward and find a white cord extending inward and backward from each. These are the **optic nerves.**

THE MUSCLES OF THE EYE.

1. Cut away the upper part of the eye sockets and find in each a muscle extending outward and backward from the anterior part of the socket to the top of the eyeball. This is the **superior oblique muscle.**

2. Another muscle coming from the posterior part of the socket will be seen passing forward to be attached under the oblique muscle. This is the **superior rectus**. Make a drawing showing these muscles. The other eye muscles may be more easily examined from beneath.

If the under surface of the skull of the specimen previously studied be not injured, it may be used; otherwise, cut off the head of another fish, and cut away completely the lower jaw and the floor of the mouth. Move the gill covers in and out to show more clearly the thin plates of cartilage between the eyes and the roof of the mouth; with scissors slit in the middle line the tough membrane lining the roof of the mouth, and strip it out to the sides. Observe a muscle running outward from each side of the base of the skull to the corresponding gill cover. Cut these at their inner ends and turn them outward. With scissors cut away the cartilages covering the under surfaces of the eyes.

3. Observe a muscle passing outward from the front part of the socket to the eyeball, the **inferior oblique muscle.**

4. The muscle running forward close to the partition between the eyes is the **internal rectus.**

5. On the under surface of the eye is the **inferior rectus.**

6. Attached to the hinder border of the eye is the larger **external rectus.** Note carefully the origin of each of these, their place of insertion on the eyeball, and their change of shape in their course; consider the effect of each on the eye.

Observe the thin-walled swellings at the sides of the base of the hinder part of the skull; cut into these **ear capsules** and find in each a membranous sac, the **vestibule** of the ear. In this sac lies the "ear bone" or **otolith.** Find the white optic nerve arising from the inner surface of the eyeball; with a sharp knife cautiously cut away the base of the skull and trace the optic nerves to the brain; demonstrate that they cross each other, the optic nerve from the right eye entering the left half of the brain, and *vice versa.*

Make a drawing showing this view of the brain and eyes; open one of the eyes and remove the spherical crystalline lens.

Topics for Reports. — The Sources, Methods of Capture, and the Commercial Importance of Food Fishes, — such as Codfish, Mackerel, Flounder, Halibut, Herring, Shad, Sardines, Whitefish, Lake Trout, Catfish, Carp, Buffalo, etc. Fish Hatcheries. The Salmon Industry. Life History of a Salmon. United States Fish Commission. Caviar. Isinglass. Cod-liver Oil. Fish Oil.

Read *American Natural History*, Hornaday.

CHAPTER IX.

AMPHIBIA.

FIELD STUDY OF FROGS.

CLAD in rubber boots, the student can visit the frogs at their home. Walk along the bank of a creek, or wade through a marsh. Try to "see the frogs before they see you." But if they see you first and jump or swim away, try to follow them up and see where they go. Do they soon reappear? How does their color suit their surroundings? Would you suggest a more suitable color? What seems to be the main idea in the colors they show? What reason for the difference of color of the dorsal and ventral surfaces? What enemies has the frog that would discover it from above? How does its dorsal color serve it? Compare its color with that of its surroundings. Why should a frog be white beneath? What enemies has a frog that would see it from beneath? What effect would the white color have? Suppose the frog were dark below; would it make any difference in the ease with which it could be seen from below? Suppose it were spotted over the ventral surface as it is over the dorsal surface? When a frog is floating, how much is out of water? What parts of it are out of water? In the spring watch the frogs that congregate in ponds. Do they all croak? If not all, which ones do the croaking? Watch to see how the eggs are laid. What are the eggs like? How are they placed? In still water or in a current? In deep water or shallow? Do any animals eat the eggs? How long does it take for the eggs to hatch? Take the temperature of the water and see if this makes any difference. Do the eggs all hatch nearly at the same time, or is there considerable difference? Do many of the eggs fail to hatch?

Again in the fall study the frogs when they gather once more along the banks. See if you can find any of them in the act of diving into the mud. Mark carefully some of these places, and watch to see if the frogs come out again. Some very slight covering of leaves or sediment may serve to show whether or not the frog has come out. How deep do they go? Do they change their depth or position during the winter? What is the temperature of the mud at this time? How cold does the mud at the bottom of creeks and rivers become during the coldest part of winter? Does it vary much during the winter?

LABORATORY STUDY OF THE LIVE FROG.

1. Put a live frog into a tub of water and study carefully its mode of swimming and floating.

2. Notice how the frog sits when at rest. Make drawings of the live frog in the sitting posture.

3. What has the frog in common with other animals that jump well?

4. Watch closely the frog's breathing, paying especial attention to the throat, nostrils, and sides.

5. Touch the eyeball with a pencil, and note what follows. Note the motions of the eyelids. Note the color of the frog's eyes. What is the shape of the pupil?

6. Test the frog's sense of hearing.

7. What does the frog eat, and how does it take its food?

8. Look for slight pulsations near the end of the backbone on each side, near the anus. These are the beatings of the **lymph-hearts.**

9. Keep one frog in the light and another in the dark and compare their colors after an hour. Vary the color surroundings to see whether they affect the color of a frog.

EXTERNAL FEATURES OF THE FROG.

Kill a frog by wrapping it in a towel or piece of cloth of any kind, and moistening the latter with chloroform; or put a tea-

spoonful of ether in a fruit jar nearly full of water, immerse the frog in it, and cap the jar.

1. Has the frog a neck? Find the division between the head and the body by bending the parts and feeling for the joint.

2. Back of and below each eye is an oval area, the membrane of the eardrum, or **tympanum.**

3. The fore limb consists of the **arm, forearm**, and **hand.**

4. The hind limb consists of the **thigh, leg,** and **foot.**

5. Count the fingers and toes.

6. What differences are there between the fore and hind limbs?

7. Open the mouth, seize the tongue with the forceps and draw it forward ; observe that it is attached in front, but free behind. How is such a tongue used?

8. Look closely for teeth. Where are they?

9. Pass a bristle tipped with sealing wax into one of the nostrils. Where does it enter the mouth ?

10. Make a small opening in one of the tympanic membranes, pass a bristle through this opening, and look for its appearance in the mouth. The opening through which it appears is the **Eustachian tube.**

11. The mouth narrows back into the gullet.

12. In the back part of the floor of the mouth is a small slit, the **glottis**, leading to the lungs.

13. Compare the colors and markings of the upper and lower surfaces of the frog; draw dorsal and ventral views of the dead specimen, naming all visible parts.

Use Jordan's *Manual of the Vertebrates* for finding the names of any amphibians.

DISSECTION OF A FROG

1. Lay the frog on its back in a dissecting pan. Stretch out the fore limbs close to one end of the board and tack to the board through the hands; then stretch the hind limbs well back and out and tack the feet so the body will be firmly held. Common carpet tacks can be set firmly enough by pressing with the thumb, and will not need hammering. With forceps pinch up a fold of skin

near the pelvis. With scissors snip through the skin in the middle line. Holding the edge of the skin with the forceps, slit the skin from the pelvis to the chin. Loosen the skin wherever it adheres to the underlying tissues, and turn it back. Cut outward in the middle of each flap of skin, and pin out if necessary to keep it out of the way. Now cut through the muscular wall of the abdomen in the same way, but be careful to keep to one side of the middle line, and thus avoid cutting the central blood tube. Be also especially careful to lift the edge of the cut with the forceps, and watch closely the lower point of the scissors to see that none of the abdominal organs are injured. When the breastbone is reached, raise it to see the heart. Now cut through the breastbone a little to one side. Loosen the tacks in the hands and set them farther out to expose the organs; tack out the flaps of the abdominal wall. Keep the specimen covered with water; renew the water if it becomes turbid.

2. Covering most of the internal organs is the dark **liver**, consisting of several lobes; note how many lobes there are and how they are arranged. Slip the handle of the scalpel under the posterior border of the liver and tip it forward. Observe the **bile sac**, a dark, usually bluish, spherical sac, connected with the liver.

3. Between the lobes of the liver at its anterior edge is the reddish **heart**. It is inclosed in a very thin sac called the **pericardium**. Pinch this up with the forceps, cut through it, then remove most of it. The heart consists of two auricles at the base, and the single ventricle at the apex, or posterior end. In a freshly killed frog the heart often may be seen beating. Time its pulsations. Running forward from the ventricle is the main artery. This divides into two branches, right and left, each of which has three subdivisions: —

a. To the head, the **carotid artery**.

b. To the body generally, the **aorta**. The two aortæ unite in the posterior dorsal part of the body cavity.

c. To the lungs and skin, the **pulmo-cutaneous**.

What is the effect of applying gentle heat to the heart, as by

breathing on it? Touch it with the point of the forceps. Does this affect it?

4. Push the liver to the right and expose the pale **stomach.** Use the blowpipe as a probe and push it back through the mouth into the stomach. For this it may be necessary to lift the anterior end of the board. Looking back into the mouth, the puckering of the gullet may be seen. Are the mouthfuls that the frog swallows small or large, relatively? What is the real width of the gullet?

5. At the posterior end of the stomach begins the **intestine**; carefully trace it throughout its course.

6. The widened portion of the intestine near its end is the **cloaca.** The external opening is the **anus.**

7. The thin membrane that holds the intestine in place is the **mesentery.** To what is it attached dorsally? In a freshly killed specimen blood tubes may be seen in the mesentery. The mesentery is a double membrane and the blood tubes and pancreas lie between the two folds.

8. Turn the stomach and intestine forward; the **pancreas** should be seen in the loop formed by the intestine and stomach. It has the appearance of a yellow cord, and is often hard to distinguish.

9. At each side of the body cavity, usually concealed by the lobes of the liver, are the two lungs. In frogs killed by chloroform the lungs are usually collapsed, that is, emptied of air; hence they are small and dark-colored. If they contain air, they may be very conspicuous and bright-colored. Find again the glottis, or entrance of air from the floor of the mouth; insert the tip of the blowpipe and inflate the lungs. They are nearly plain, hollow sacs, and not spongy all the way through like the lungs of the mammals. Tie a thread tightly around the base of each lung while it is inflated; cut the lungs out and hang them up till they are dry. Then cut one of them open and compare it with the lung of a turtle similarly prepared.

10. Insert the scalpel handle under the posterior end of the stomach, and tip it forward with the intestine and the liver. On

each side of the cloaca is a flattened reddish body, the **kidney**. The ventral face of each usually shows a yellowish streak.

11. Near the ventral surface of each kidney, in the male frog, is the white, oblong **spermary**.

12. In the female, the **ovary** occupies a corresponding position; but often the ovaries are found greatly distended by eggs, so much so that they occupy the larger part of the body cavity. The eggs are black and white. The ovaries are held within the two folds of the mesentery, hence, when distended with eggs, they present a much folded and plaited appearance. The **oviducts** are long, convoluted, whitish tubes, occupying considerable space in the dorsal part of the body cavity on each side. With fine scissors make a small slit in one of the oviducts near the posterior end, and insert a dark bristle to find the opening into the cloaca. Make a similar opening near the anterior end of the oviduct and probe to find the opening by which the eggs enter the duct at its free end in the body cavity near the base of the lung.

13. Connected with the ovaries and spermaries are usually several fingerlike masses of yellow fat.

14. Close to the anterior end of the cloaca is the small, red, spherical **spleen**.

15. In the extreme posterior end of the body cavity is the **urinary bladder**. It is a thin, delicate sac, which is usually found empty, and floats upward in the water like a mere fold of nearly transparent membrane. Insert the blowpipe through the anus and inflate. This should reveal its shape and size, if it has not been perforated.

The Circulation of Blood in the Web of a Frog's Foot. — For this get a frog with a pale web. Take a piece of shingle six inches long and three inches wide. Cut a round hole, half an inch in diameter, near one end of it. Wrap the frog in a wet cloth, with one leg projecting, and tie it, thus wrapped, to the shingle. Tie threads around two of the toes, and stretch the web, but not too tightly, over the hole. Place the shingle firmly on the stage of a microscope. Examine first with a low power. The large tubes

which grow smaller by subdivision are **arteries**. The large tubes which are formed by the union of smaller ones are the **veins**. The finer tubes, forming a network in every direction, are the **capillaries**. They receive the blood from the arteries and pass it on to the veins.

Put on a higher power, a one-fifth or one-sixth objective. Study the little bodies floating in the blood. These are the **corpuscles**.

1. The colored corpuscles. The faintly colored elliptical corpuscles; do they change their shape when pressed, as in turning a corner? What is the color of these corpuscles? Mold a bit of clay into the shape of one of these bodies.

2. The colorless corpuscles. The smaller, rounder, paler corpuscles, fewer in number and moving with a slower and more unsteady motion along the sides of the channel, — what must be the shape of these? Place a drop of frog's blood on a slide, cover with a cover slip, and examine with a high power. Make careful drawings of the two kinds of corpuscles.

THE NERVOUS SYSTEM OF THE FROG.

The nervous system is better seen in alcoholic specimens. Slit the skin along the back from the snout to the anus; with a sharp knife cautiously cut away the top of the skull, and find: —

1. Between the eyes, side by side, two elongated white bodies, the two halves, or **hemispheres**, of the **cerebrum**. Observe two small, pear-shaped bodies, the **olfactory lobes**, in front of the cerebral hemispheres. These taper forward into nerves running to the nasal region; these are the nerves of smell, or **olfactory nerves**.

Back of the cerebral hemispheres are the **optic lobes**, forming the largest part of the brain. Prove that a white cord, the **optic nerve**, connects each of these lobes with one of the eyes; does the optic nerve extend directly from each eye to the corresponding optic lobe? Loosen and raise the brain from the front to prove these points.

3. Extending backward from the under side of the optic lobes is the **spinal bulb**.

4. The spinal bulb narrows and becomes the **spinal cord.** Trace the spinal cord back into the spinal column, cutting away the part of the backbone that covers it.

5. In the body cavity find nerves emerging from the sides of the spinal column, hence called the **spinal nerves.** Find that several of these, after running backward, unite to form one large nerve. Trace the nerve down between the muscles of the thigh; this is the **sciatic nerve.**

REFLEX ACTION OF THE FROG'S SPINAL CORD.

Chloroform a frog as directed on page 83. As soon as it becomes insensible find, by bending the head, the joint between the head and the backbone; lay the frog on a board, and quickly thrust the blade of a knife through the body at this joint, and completely sever the spinal column and spinal cord. This is essentially the same as cutting off the head. Run a wire into the brain cavity and stir it about in order to destroy the brain. In a few minutes hang the frog by a hook through the jaw.

1. Pinch the toes; what follows? Repeat the experiment several times. Pinch the skin near the anus.

2. Slit the skin along the back side of the thigh; tear apart the muscles, and find the sciatic nerve; with a sharp pair of scissors (while watching closely the foot) sever this nerve; what takes place?

3. Hang up as before, and pinch the toes of each foot; what difference is now observed?

4. With the forceps alternately pinch the two ends of the severed sciatic nerve; what takes place as the two ends are pinched?

5. Run a wire down the spinal column, twisting it about to destroy the spinal cord; what occurs while this is doing?

6. Pinch the toes as before; what results?

7. Again pinch the end of the sciatic nerve, still connected with the parts below, being careful to pinch a little lower than before.

The Action of a Frog's Muscle. — Kill a frog thus: Into a fruit jar of water put a teaspoonful of ether; immerse the frog in it and cap the jar. As soon as the frog is motionless cut off its head and run a wire down the cavity of the spinal column, to destroy the spinal cord. Cut through the skin around the base of one of the thighs, and strip off the skin from the whole of the limb. Note that the muscles are of a pale color. The muscles of a frog's thigh are nearly the same in number and arrangement as in man. Examine more thoroughly the calf muscle; the end by which it is attached below is its **insertion**, and the upper attachment is its **origin**. The white cord in which it ends is its **tendon**. This tendon is often called the "heel cord," or Achilles' tendon.

Sever the limb from the body at the hip joint. Separate the muscles along the outer back part of the thigh, and find the white, threadlike **sciatic nerve**. The nerve must be handled with great care; it must not be pinched or dragged. Carefully separate it from the surrounding muscles, and turn it down upon the calf muscle. Cut away all the muscles of the thigh, being careful not to touch the nerve where it runs down by the knee. Sever the heel cord below the heel, and separate the calf muscle from the rest of the leg, leaving undisturbed its attachment above; just below the knee cut away the shin bone, with all the muscles of the leg except the calf muscle.

There should now remain the **thigh bone**, with the **sciatic nerve** running to the **calf muscle** suspended below. Fasten the thigh bone to some support, such as a clamp on a retort stand. Attach a small hook to the tendon, and suspend from it a slight weight, such as a small key.

Such a preparation is called a **nerve-muscle preparation**. It should frequently be moistened with a .7 per cent solution of common salt in water, called **normal saline solution**.

Now take a sharp pair of scissors, and snip off the shortest possible portion of the upper end of the sciatic nerve. If the muscle is closely watched at the time when the nerve is cut, it will be seen to thicken and shorten, and to lift the weight. If the muscle

be held between the thumb and finger while the nerve is pinched (and the scissors are the surest pinchers), it will be felt to harden.

This experiment should be repeated, varying the weight, until it is made very clear that when the nerve is stimulated the **muscle shortens** (which is the most important fact about the action), thickens, and grows harder.

Observe the thin, transparent membrane covering the muscle, the **muscle sheath**. Tear the muscle to pieces, and note its fibrous structure. Put a bit of the muscle in a drop of water on a slide, and cover with a cover slip; examine first with a low, and then with a high, power, to see the cross markings of its finest fibers. This kind of muscle is called **striped** or **striated.**

PREPARATION OF A FROG'S SKELETON.

Remove the skin and all the soft tissues. If you have a specimen that has been used for dissection, of course the anterior limbs will come apart where the breastbone was severed. Remove the soft tissues mainly by means of the scissors, being careful not to cut too close to the joints. If the work is not completed at once, return the specimen to the water. Renew the water frequently and do not allow it to "get bad." If the ligaments decay, the bones will fall asunder and make great difficulty on account of their number and smallness. Do not boil the skeleton, or put it into alkali. These processes may be useful for larger skeletons, but are not good for such small ones as that of the frog.

MOUNTING A FROG'S SKELETON.

Get a piece of stiff, dark cardboard about six by eight inches. Before mounting the skeleton on the card, get it nearly dry by placing it on blotting paper or on cloth. If it is too dry, it will be brittle; if too wet, it will stain the card. Draw a fine pencil line along the middle of the card. Place the skeleton along this line and double up the limbs as if the frog were in the resting position. A block of cork must be placed under the anterior end of the spinal column to hold it up to the level of the skull. A small

cork wedge should be placed between the jaws. The skeleton is to be sewed to the card with a single thread of the color of the bones. The bones are to be held by loops that pass up from the under side of the card, around the bone, and back through the same hole. *All holes are to be punctured from the upper surface of the card*, and are better made with a pin slightly larger than the needle used in sewing. It is important to determine exactly where each bone is to lie, so that the hole may be made exactly under the middle of the bone. Now puncture holes as directed under the front and hind angles of the jaws, and under the pelvis beneath the hip joints. After securing the head and pelvis, determine carefully where the bones of the limbs are to rest. Pass loops around near each end of the longer bones, but a single loop in the middle will serve for the short bones of the fingers and toes. If the skeleton is from a specimen used for dissection, the breastbone will have been severed. Bring the cut ends together and sew firmly in place. The shoulder blades should meet in the middle line a short distance back of the skull. Print the label "Skeleton of a Frog" at the foot of the card and write your name on the back of the card.

To preserve the skeleton get a shallow box, such as a shallow cigar box. Fit the card to the box and tack it to the bottom. A good plan is to remove the wooden cover and replace it with a glass lid. Paste strips of paper or suitable cloth along the edges, and the case will exclude dust.

THE FROG'S SKELETON.

1. Note how open and light the skull is, and how easily the bones are cut.

2. Count the parts of the spinal column; these are the **vertebræ**. The long bone terminating the spinal column is the **urostyle**.

3. Observe the long bones of the **pelvis**, parallel with the urostyle. What makes the frog humpbacked?

4. The fore limb has, in the upper arm, the **humerus**; in the **forearm**, the **radius** (same side as the thumb) and the **ulna**; in the

wrist are several small bones, the whole collectively called the **carpus**; in the hand are the **digits**.

5. The hind limb has, in the thigh, the **femur**; in the leg, a bone which shows, by grooves near its ends, that it is formed by the union of the two bones corresponding to the **tibia** and **fibula** of man; the several small bones of the ankle are together called the **tarsus**; the bones of the toes are the **digits**.

6. Are there any ribs?

STUDY OF A TADPOLE.

Get a number of frog's eggs and place them in a jar of water. If many eggs are placed in a small amount of water, the eggs are not likely to develop well. Set different jars in different places with regard to light and heat, and note any differences in results. It is best to have some aquatic plants in the jar, especially after the young have hatched out. How long before the tadpole within the egg begins to move? How long till it breaks away from the egg mass? How early do the gills show themselves? What are the parts of the tadpole? What is the shape of the tail? What is its use? How is it used? How early do legs appear? Which legs develop first? Is there any reason for this? Are tadpoles relatively active or inactive? Do they move much "of their own accord"? Or chiefly when they are disturbed? Does the tail fin have supporting rays like the fin of a fish? What do tadpoles eat? How do they eat? Have they teeth? Is the growth slow or rapid?

Put a tadpole in a watch glass of water under the microscope, with a half-inch or two-thirds-inch objective, and watch the circulation of blood in the gills. What becomes of the gills? Watch the sides of the body for a hole where water escapes. Where is it? Why is the tadpole not symmetrical in this respect? What becomes of the tail as the tadpole becomes a frog?

Examine a dead tadpole to see if there are teeth. What is the size of the mouth in proportion to that of the adult? Look again for the hole on one side of the body. Are there ever limbs con-

cealed? Open the body cavity. Is the digestive tube long or short as compared with that of the frog? What reason for this? Can you find any traces of gills? Of lungs? Is there a backbone? Do you find a brain and spinal cord?

Make a series of drawings showing the different stages of development.

Topics for Reports. — Frogs as Food. The Axolotl. Value of Toads. The Tree Toad.

Read *American Natural History*, Hornaday.

CHAPTER X.

REPTILIA.

FIELD STUDY OF SNAKES.

FIRST try to rid yourself of prejudice against snakes. It is not necessary to handle them, and poisonous snakes are now rare in most places. If the snake has been frightened by you, try to learn how he became aware of your presence. Was it through sight, hearing, or some other sense? Is there any plan in his escape? Does he seek shelter, or simply move away from you? Are his colors such as to aid him in escaping enemies? Why are we usually surprised when we happen upon a snake? Is the snake also surprised?

Study the snake's mode of locomotion. Have you ever seen the trail made by a snake, as in a dusty road? Does the nature of the surface make any difference in the ease with which it travels? Does a snake ever crawl otherwise than in a wavy line?

If you happen upon a snake that has not already discovered you, watch it. Try to find out what it is doing. Especially if you find a snake eating, take time to learn how it eats. Does it kill the prey before swallowing it? Does it chew its food? If you kill a snake, or see one killed, where you cannot take it home, find out, if possible, what it has been eating. If the snake is much bulged out at, or in front of, the middle, you may suspect that it has just swallowed a meal. Do snakes "charm" birds?

Have you ever found a shed skin of a snake? If you find one, bring it to the class. How much of the external markings is shown on the shed skin? Can all snakes swim? If you get a garter, or other snake, not a water snake, and do not wish to keep it, throw it into water to see if it can swim. Will the body of a

freshly killed snake sink or float? Do snakes dive? How do snakes strike, when capturing prey or in self-defense? How far can a snake strike? Let it strike some object, for example a stretched paper, to show with what force it strikes. Do you *know* of any case where a snake, unmolested, pursued a human being?

LABORATORY STUDY OF A LIVE SNAKE.

A snake may be kept in a large glass jar, but it is better to have a shallow box, with glass lid. Test the snake's vision. Does it see well? Does it see small objects as readily as large ones? Does it notice slow motions as well as quick ones? Test its sense of hearing. Try music. Does the snake protrude the tongue? If so, for what purpose?

Induce the snake to strike; study the position and mode of striking. Study the process of respiration in the snake. Is there a pause? What movement is first after the pause? Compare the snake's respiration with your own. Does a snake need much or little oxygen as compared with man?

How soon does a snake become hungry after a meal? Offer various articles of food. Does a snake drink? Offer it water in a shallow dish from time to time. Will a snake eat a dead animal? Do snakes of different kinds in the same box offer to molest each other? Do snakes ever eat snakes of any kind? Do snakes sleep? At what times are they most active? When least so? Watch a snake to see the shedding of the skin. At what point does the skin begin to loosen? How is the skin peeled off? What is the condition of the snake before shedding? What is the appearance and condition after shedding? How often does a snake shed its skin?

EXTERNAL FEATURES OF A SNAKE.

Examine the scales; observe their relation to each other and to the skin. A scale having a ridge running lengthwise in the middle line is **carinated**; if there be no such ridge, the scale is called **smooth**. How many rows of scales are there, not counting the

wide ventral plates below? It is usually easier to keep the count by following the row of scales **obliquely** across the body.

Use Jordan's *Manual of the Vertebrates* for finding the names of any reptiles found in your vicinity.

DISSECTION OF A SNAKE.

Get a large snake, a paper of tacks, and a board as long as the snake. The board should be of dressed soft pine so that the tacks may be inserted by the thumbs; a hammer should be unnecessary, tho if the spinal cord is not destroyed, the body may pull with considerable force, and it may be desirable to drive a six-penny nail firmly through the tail just back of the anus. Lay the snake on its back, with the head at one end of the board. Push the point of a tack into the mouth at one side, and drive it through the upper jaw, leaving the lower jaw free. Repeat with the other side. Stretch the snake out straight, and tack through the tail, just back of the vent. With the forceps pinch up a fold of the skin of the throat, and cut through it with the scissors. The greatest danger is that of cutting into the air sac, which, when distended, fills most of the space of the body cavity. To guard against cutting into it push the handle of a small sp[illegible] or the bowl of an "after-dinner coffee spoon," along under t[illegible] ahead of the scissors so the lower point of the scissors shall [illegible] constantly guarded. Continue the cut back along the middle line of the ventral wall, being very careful not to cut anything within. As the cut proceeds, stretch the skin out at the sides, and tack it down every two or three inches. Cut away the thin membrane which extends across from the ribs on each side, avoiding blood tubes.

1. With forceps seize the lower jaw and pull the mouth open. Note how dilatable the mouth is, and how loosely the lower jaw is hinged to the upper; note, also, that the right and left halves of the jaws do not unite in front. Examine closely the **teeth**, their shape and arrangement. In what direction do they point?

2. Seize the **tongue**, and draw it forward from its sheath in the floor of the mouth. Observe its black, forked tip.

3. Above the tongue find a small opening, the **entrance to the windpipe.** It is called the **glottis.**

4. Take six inches of glass tubing half an inch in diameter; slip over the end of this a piece of rubber tubing a foot long; this will enable you to see the effect while you are inflating. Insert the glass tube into the throat through the mouth; pinch the walls of the gullet closely around the blowpipe, and inflate the wide **gullet** and **stomach.**

5. For inflating the lung, a tube with a small point is better; draw out a small glass tube, and connect with a rubber tube; insert the point in the glottis, and inflate. This locates the pink **lung,** with its posterior, thin-walled extension, or air sac. How far back does the air sac extend?

6. Trace from the glottis to the lungs the ringed windpipe, or **trachea.** Only one lung is developed; look for the rudiment of the other.

7. In a freshly killed snake the heart will be noticed on account of its beating; the part of it farthest from the head is the **ventricle**; nearer the head find two parts, the right and left **auricles.** These two contract at the same time, just before the contraction of the ventricle. The heart is in a thin sac, the **pericardium**; pinch up a fold of this with the forceps, and cut into it, and remove that part of it covering the heart, very carefully avoiding blood tubes.

8. Find a blood tube arising from the ventricle just between the auricles, and passing forward between them, curving around over the gullet to the posterior part of the body. This is the main artery, or **aorta**; look for its branches running to the head.

9. Look also for an artery running to the lung, the **pulmonary** artery.

10. Find several **veins,** of a darker color than the arteries, leading to the heart.

11. Alongside the stomach is a dark red body, the **liver**; a large vein runs along its surface.

12. Back of the liver is the dark **bile sac**; the ducts from the liver to the bile sac, and from the bile sac to the intestine, are not easily seen.

13. Just posterior to the bile sac is the spherical, reddish **spleen.**

14. Closely following the spleen is the pale, roundish **pancreas**; the duct by which its secretion is conveyed to the intestine is hard to find.

15. Clear away any masses of fat that may hide organs in the posterior part of the body, and expose the **intestine** from the stomach to the anal opening.

16. The enlargement of the intestine near its termination is the **cloaca.** Again inflate the stomach; does this also inflate the intestine?

17. If the specimen is a female, there may be found, in the posterior part of the body, the whitish **ovaries**, with a row of white eggs; from the ovary, the **oviduct**, a slender pinkish tube, extends back to enter the cloaca. Are the ovaries of the two sides opposite each other? Slit into one of the oviducts near the cloaca; insert a bristle and find where it enters the cloaca.

18. In the male the white **spermaries** have similar positions. Their ducts are called **sperm ducts.**

19. Farther back than the ovaries are the dark red, elongated **kidneys.** Describe them. Trace their ducts, the **ureters,** to the cloaca.

20. Count the ribs of one side.

21. Draw the points of the forceps quickly along the muscles over the ribs; note the shortening of the muscles that follow; such action of the muscles is wholly involuntary (as the brain now has no connection with the body), and is called **reflex action of the spinal cord.** It is the same kind of action as that seen in the case of a chicken with its head cut off.

PREPARATION OF A SNAKE SKIN.

After finishing the dissection according to the above directions, completely remove the skin, retaining only the skull. Thoroughly rub the inside with arsenic. Make a wooden body, around which wrap a little cotton, and sew up as neatly as possible. Try

to preserve the original size of the snake. Lay the prepared skin on a shelf till it is dry. Keep it in a dust-proof case.

Topics for Reports.—The Cobra. Other Venomous Snakes. Do Snakes swallow their Young? The Python. The Boa Constrictor.

FIELD STUDY OF TURTLES.

The student soon learns that the common pond and mud turtles are shy creatures. Along ponds and streams one may see them on logs and stumps. But one must go quietly and cautiously, or he will scare them all into the water. On which sense do they rely, sight or hearing, to discover enemies? Watch their method of getting into the water. Do they soon return, if the observer is quiet? What seems to be their object in thus perching on logs Find out, if you can, what they eat, and whether they eat on land or in water. Do they require much or little food?

Can you find where and how they lay their eggs? Do they care for the eggs? How long does it take the eggs to hatch? Do the parents care for the young? What are the prevailing colors of turtles? How do these colors compare with their surroundings?

STUDY OF A LIVE TURTLE.

Watch a turtle walk on a floor. Does it walk or crawl? Is the body lifted above the surface or does it drag? How are the limbs used? Put the turtle in water and find out how it swims. Does it use the front feet alternately or at the same time? Are the feet webbed? Does it swim rapidly or slowly? Does the turtle dive? If there is mud at the bottom, does it attempt to burrow into or bury itself in it?

Feed the turtle and find what it likes best. Does it eat little or much? Do turtles become tame in captivity? Do they recognize those who care for them, and distinguish them from strangers?

Can you see how the turtle breathes? Can it stay under water long?

What parts of the turtle can be protruded beyond the margin

of the shell? How does it protect these parts? Can any part of the shell be moved, or is it wholly rigid?

EXTERNAL FEATURES OF A TURTLE.

1. The upper part of the shell is the **carapace.**

2. The under part is the **plastron.**

3. Observe the large sections, or **plates**, marking the shell. How many of these plates are there on the carapace? How many on the plastron? How are they arranged?

4. Study the motions of the head, legs, and tail; observe the **scales** on these parts.

5. Note the shape of the feet; for how many purposes does the turtle use its feet? Are the feet of all turtles alike? Count the claws; compare the front and hind feet.

6. With a strong pair of pinchers seize the head, pull it well out, and chop it off; examine the mouth; are teeth present? Is there a tongue? Look for a third eyelid. Compare with the pigeon in this point of structure.

DISSECTION OF THE TURTLE.

Saw through the bridge which connects the carapace and plastron on each side. Carefully raise the plastron, and, keeping the blade of the knife or scalpel close to its inner surface, cut away all its attachments to the organs within, and remove it entirely.

1. In front are the bones supporting the fore limbs.

2. Behind are the bones of the **pelvis**, supporting the hind limbs. Were these two sets of bones attached to the plastron?

3. A thin membrane covers the internal organs; through it the **heart** may be seen beating. Cautiously avoiding blood tubes, cut away this thin covering, and distinguish the following parts of the heart: —

a. The large, hinder part, the **ventricle.**

b. In front, on each side, the two **auricles.**

c. Between the auricles are blood tubes, branching toward the

head. As in the frog, there are two aortæ, the right and left, which unite posteriorly.

4. Make out the following order of the heart's beat: —

a. The contraction of the blood tubes leading to the auricles.

b. The contraction of the auricles.

c. The contraction of the ventricle.

5. On each side of the heart appears the dark **liver**, consisting of two main lobes, connected by a cross-band. Search the liver to find the **bile sac**.

6. Under the left lobe of the liver is the **stomach**.

7. From the stomach trace the intestine to the transverse vent under the tail.

8. Masses of eggs may be found in the **ovary** (if a female).

9. Find a large bladder near the pelvis.

10. Raise the liver to find the **lungs**; pull forward the neck, find the windpipe, and insert a blowpipe. By inflating, the lungs may be better seen. When the lungs are fully inflated, tie a string tightly around the windpipe; carefully remove the lungs, and hang them up to dry. When they are thoroughly dry and firm, cut them across, and compare with the lungs of the frog and rabbit.

11. How does the turtle draw in its head?

12. How long does the heart beat after the head is cut off?

THE SKELETON OF THE TURTLE.

1. Clean away the muscles and all soft parts. Boiling loosens the outer plates; these are parts of the skin, and not of the skeleton proper; they are called the **epidermal plates**.

2. When these plates are removed from the carapace, there appears a series of bones extending outward on each side; these are the ribs, very wide, and united by their edges. How many of these flattened ribs are there?

3. On looking at the inner surface of the carapace, the series of **vertebræ** will be found; and attached to the sides of the bodies of these vertebræ are the heads of the ribs.

4. Along the middle line of the outside of the carapace, between

the ribs of the two sides, is found a series of bony plates; these are the enlarged and flattened projections of the vertebræ; they correspond to the spines which make the sharp ridge along the backs of most vertebrates.

5. Compare the bones of the pelvis and of the limbs with those of the rabbit.

Topics for Report. — The Terrapin. The Hawkbill Turtle. Tortoise-shell. The Loggerhead Turtle. The Green Turtle. The Snapping Turtle. The Soft-shell Turtle. The Gopher.

Read *American Natural History*, Hornaday.

CHAPTER XI.

AVES.

OUTDOOR STUDY OF BIRDS.

THE following set of questions is general and may be applied to any bird that comes within our range of observation. The English sparrow serves well for study, since — like the poor — it is always with us. These studies should include a careful study of the domesticated birds.

Place of Living. — Does the bird stay most of the time on the ground or in the trees? In open fields or in thickets? In open woods, or dense forest? On dry soil, or along the water? Is it fitted for perching, running, swimming, wading, climbing, or for what general kind of life?

Flying. — Does it fly swiftly or slowly? Do the wings vibrate rapidly as in the quail, or slowly as in a hawk? Is the vibration uniform, or do the wings make a series of rapid motions, followed by a rest during which time the bird sails, as with the quail? Is the flight quiet as in owls, or accompanied by a whirring sound as with a quail? Is the flight in comparatively straight lines, or in loops or festoons, as with woodpeckers? Does the bird ever "soar," or "hover"? What is the use of the tail in flying? How are the legs and feet held during flight? Why do some birds fly most of the time while others fly little? What characteristics have the birds that spend much of the time flying? Name some of the best flyers you know. Name some of the poorest flyers that live near you.

Walking. — What birds really walk? Why do so many birds hop, while on the ground, instead of walking? Do you know any

birds that prefer walking or running and seldom fly unless frightened? Is there any special adaptation of the feet in birds that spend most of the time on the ground? Compare the size and strength of the legs in birds that live on the ground with those of ordinary perching birds.

Food.—What does the bird eat? How does it discover this food? How does it secure it? Does it eat much or little? Has it any special time, or times, of day (or night) for feeding? Give particulars of the manner of feeding. Does it store food, or simply get what is needed for the present? If stored, how and where? Name any special adaptations for obtaining special kinds of food. How do birds drink?

Sociability. — Do birds live singly, in pairs, or in flocks? Do any birds that live in pairs during the breeding season ever flock at other seasons? Does the kind of bird you are studying mingle freely with other birds, or does it keep aloof? If they "meet by chance," are they shy? Do they quarrel? Are they inclined to be "quarrelsome"? Does one kind try to drive another away? Does the larger always defeat the smaller?

Nesting. — Does a bird habitually build in the same kind of place? Is the place selected with reference to enemies? To shelter? Do any prefer to rebuild in the same place? Of what material, or materials, is the nest made? How is this material obtained? How is it carried? How is it "handled" during the building? Do both sexes share in the nest building? Is the size of the nest, as seen from the outside, in keeping with the size of the bird? Is the space inside in proportion to the body? How many eggs are laid? Are they arranged in any definite way? Their color? Size? Shape? Is the shell thick or thin? How long from the time of beginning to "sit" till the young hatch out? Does the male ever "sit"? Does the male ever bring food to the female while she is "sitting"? What proportion of the eggs hatch? Do birds ever lay eggs in the nests of other birds? If so, do they lay them in nests of the same kind of bird? Are the

young able to get their own food as soon as they are hatched, or are they helpless? How fully feathered are they when hatched, and are the feathers the same in color and texture as in the parents? Which do they more nearly resemble, the adult male, or the female? On what are the young fed? Is food ever especially prepared for the young? Do both parents bring food? Do the young require much or little food? Are their eyes opened as soon as they are hatched? How long till they leave the nest? Till they can fly? Are they cared for after they leave the nest? Is the nest a "home"? Do the young return to the same spot? Do they ever occupy an old nest? Do they use any of the material of an old nest?

Migration. — Make a list of the birds that you see remaining here during the summer. Make another list of those that stay with us during the winter. Why do some of these birds go south in winter while others remain the year round? Is the blue jay any more warmly clad than the robin? Or is there some other reason than mere ability to "stand the cold" that leads one to stay while the other migrates? Do you see birds in the fall and spring that are not seen here either in winter or summer? How do you account for these facts? Make a list of birds that are seen only during fall and spring. Do birds migrate singly or in flocks? Or in pairs? Do you see in winter any birds that are not here in the summer?

Songs. — How many objects have birds in using the voice? How many distinct kinds of calls has this bird? Can this bird be said to sing? Do birds have a language?

Care of Feathers. — How do birds arrange their feathers and keep them in good condition?

Molting. — When do birds appear brightest and freshest? What makes the difference? Are all birds alike in these changes? Examine birds to find evidence of change.

Senses. — Can birds see well? Hear well? Experiment to test their senses.

Attitude. — Note closely the attitude assumed by the bird when at rest. In the case of tree birds observe whether they rest crosswise or lengthwise on a branch, whether erect or nearly horizontal, whether they prefer large branches or small ones, etc. Where and how do the different kinds of birds spend the night? What birds are astir at night?

Color. — Note the relation of a bird's color to its ordinary surroundings. What differences in the color and markings of the male and female? How do you account for these differences?

INDOOR STUDY OF BIRDS.

While the writer does not wish to encourage the caging of birds, it may sometimes be profitable to keep a bird in confinement for a time to study some of its habits that might escape observation in the free bird. A pigeon or canary will serve very well for this work. Suitable cages should be provided, and the bird should be well cared for. Try to make the bird feel as much at home as possible. Find what it prefers to eat, and learn its habits of eating and drinking. Learn how a bird winks. How does it sleep? How does it perch? Watch the breathing movements. Count the respirations for a minute when the bird is not especially excited. If possible, test the temperature of a bird by holding a clinical thermometer under its wing for a few minutes. (In this experiment be careful not to let the bird knock the thermometer out of your hands.) Close all the doors and windows and let the bird fly about the room to see how it flies. Study the actions of the wings and tail. Hold the bird by the body and when it flaps its wings learn what you can of their action. Can you determine definitely how the wing is moved in what we call the "down stroke"? At what angle is the wing held during this stroke? In the same way study the up stroke. Hold the bird above you and below you, with the head toward you and with the tail toward you, and note in which direction it fans the air most strongly.

In this work make use of canaries, parrots, and other of the commonly caged birds. Study the birds found in zoölogical gardens.

To what extent, and in what manner, do birds evince emotion such as anger, fear, etc.? Try bringing close together cages containing different kinds of birds. How much attention do they pay each other? Try placing a mirror close to a caged bird. Are birds affected by music? By harsh or loud noises?

If an owl can be captured alive, much can be learned from it. Give it a dead bird or mouse. See how it eats. Watch to see the pellets of hair and feathers that it ejects from the mouth after digesting the soft tissues. If a swimming bird can be kept, one may see how it swims. A tame duck may serve well for this. Drop a dead bird into a pail of water. Does it sink? Pluck the bird and again drop it into the water. Does it sink or float? Explain. How is it that birds keep so warm while flying in very cold air, as in winter when it is below zero? Do birds have parasites? Do they make effort to get rid of them? Can you help the birds get rid of them?

EXTERNAL FEATURES OF A BIRD.

How to handle a Bird. — Feathers are delicate structures and, if once crushed or broken, cannot be made over again. Never stroke feathers unless necessary. Above all, never draw a feather through the fingers. This ruins the texture forever. When needed smooth the feathers and deftly rearrange those that are displaced or twisted. When possible pick up a bird by the bill, not by the legs or tail. To take a bird in hand, pick it up by the bill and gently draw it into the other hand, back down. To lay it on the table, draw it lightly from the palm upon the table. To examine the tail feathers, hold the bird with its head toward you and with the thumb and fingers of the two hands take hold of the base of the tail and spread the feathers. Do not take hold of the tip of a feather, and it is seldom necessary to take hold of any part but the base of the quill. To examine the wing quills have the head of the bird toward you, and, passing the thumb and fingers by the front edge of the wing, hold the quills by their bases. Never pull a bird backward on the table by the legs or tail.

The Head.

1. The **beak** consists of the upper and lower **mandibles**; hold the pigeon's head with one hand, and with the other take hold of the tip of the upper mandible and see if it is movable.

2. Raise the upper eyelid, and look in the front angle of the eye for the third eyelid; seize the edge of this with the forceps, and pull it backward over the eye.

3. Brush forward the feathers below and back of the eye to find the **ear opening**; observe the peculiarities of the feathers which cover this opening.

4. Examine the **nostrils**; open the mouth and insert the head of a pin into the nostril, and probe, to discover its place of appearance in the mouth.

5. With the forceps pull forward the **tongue** for careful examination.

6. Just back of the tongue is the opening, the **glottis**, of the **windpipe**, or **trachea**.

7. The mouth continues backward to become the gullet.

The Legs.

1. Feel of the parts, beginning close to the body, to be sure to find the first division of the limb; this is the **thigh**, or "second joint."

2. Below this is the **tibia**, or "drumstick."

3. The next division is the **tarsus**; it is a consolidation of several bones that were distinct in the young bird; this part of the bird's leg, then, really corresponds to the tarsus and metatarsus of the human foot, or that part between the ankle and the toes. Where, then, is the true heel?

4. Bend and extend the **toes** to find how many bones there are in each.

5. The scales on the front of the tarsus are called **scutella**; hence the tarsus of the pigeon is said to be **scutellate** in front; the back of the tarsus of the pigeon is **reticulated**.

6. Bend the leg up close to the body in the position it has when the bird settles on its perch. What effect has this on the toes? Note the position of the toes when the leg is straightened.

The Tail.

1. Count the quills of the tail; spread the tail to see their mode of overlapping; make a diagram to show their mode of overlapping as seen from behind; mpare the middle and outer tail feathers.

2. The feathers which lap over the base of the tail are the upper and lower **tail coverts**.

3. Raise the upper tail coverts to find the conical tip of the outlet of the oil gland; press the oil gland to get a drop of oil.

4. In front of the lower tail coverts is the **anus**.

The Wings.

1. Feel of the wing to make out the division into **arm, forearm**, and **hand**.

2. The foremost angle of the wing is called the **bend of the wing**. To what part of your arm does this bend of the wing correspond? Just outside of the bend of the wing find the **false wing**, a cluster of short quills, borne on the **thumb**.

3. The long **quills** borne on the hand are the **primaries**; count them. The quills on the forearm are the **secondaries**; count them. When quills are found on the arm, they are called **tertiaries**.

4. The shorter feathers which overlap these quills above and below are the upper and lower **wing coverts**.

5. Extend the wing; compare its upper and lower surfaces; observe the shape of the quills, and the way they overlap one another; put all these facts together and consider their effect in the down stroke of the wing. What is the result of this arrangement when the wing is moved quickly upward?

6. Extend the wing and hold it squarely in front of your face. Send a quick puff of breath squarely against the under surface of

the wing. What effect does this have on the individual feathers and the wing as a whole?

7. Repeat the experiment with the outer surface of the wing, noting carefully how each separate feather is acted on, and what is the effect on the wing itself. What is the effect of the wing on the air current in each of these experiments?

The Feathers.

1. Pull out one of the large wing quills and study its parts; the central axis is the **shaft**; the expanded part is the **vane**; the side branches of the shaft are the **barbs**, and the side branches of the barbs are the **barbules**. With a lens examine the upper and lower surfaces of the vane; then tear one of the barbs loose from the barbs in front of and behind it, and study it carefully; again watch closely while tearing two barbs apart, to see how the barbules are related to each other; now examine the vane of the same quill at the very beginning of the vane, near the end that was attached to the wing. What is the difference between the arrangement of the barbs in these two places? Observe the hole in the tip of the shaft; run the point of a dissecting-needle along the groove in the under surface of the shaft toward the base of the shaft. This should lead the point of the needle into another opening, communicating with the cavity of the shaft. Examine this region with a lens, and determine that the two sides of the vane meet at this point. Make drawings of a quill, as seen from above and below, showing all these points.

With sharp scissors cut across the feather in the middle of the vane. Look at the cut end; observe that the vane is attached to the **upper edges** of the shaft; compare the place of attachment of the vane to the shaft, with the place of attachment of the wing to the body. Cut part of the wider side of the vane at right angles to the barbs; with a lens, or a low power of the microscope, examine the edge of this cut. Make drawings showing these arrangements of the parts of the quill. What are the advantages of such arrangement?

2. Take one of the body feathers, and compare it with the quill. In what lies the chief difference?

3. Find a feather that is wholly composed of "down," if there be such; examine the "down" with a microscope.

4. Pick a small part of the breast, and study one of the fine, hairlike **pinfeathers**. How does it differ from the feathers already examined?

5. Take a primary feather that is in good condition and set it erect in the hole in the end of a trunk key. The hole should be deep enough to hold most of the length of the free end of the quill, but must not be so deep as to catch the vane and interfere with the free rotation of the feather. Instead of a key you may use a spool, piece of glass or metal tubing, or anything with a smooth hole of suitable depth and width. Now hold the feather, thus supported, vertically before your face and gently blow against it. How does the feather turn? In what position does it remain? Try this with the feather in different positions at the beginning of the experiment. Compare the results of this experiment with the observations made in blowing against the inside and outside of the wing, and explain the advantages of the shape, structure, arrangement, and mode of overlapping of the feathers. Try the breath on the secondary feathers as above directed. If you were using a quill for a pen, would it make any difference what kind of a feather you took? Would it make any difference whether it came from the right wing or the left wing?

6. Study the arrangement of the feathers; do feathers grow on all parts of the body? A fledgeling shows this point well. Push aside the feathers along the line of the ridge of the pigeon's breastbone and examine the skin; do feathers grow here? Look for other unfeathered areas. Note how the feathers overlap.

7. Pick the feathers from one side of the pigeon, just to the middle line; lay the bird on the feathered side, and make a drawing, showing (1) the outline of the feathers, and (2) the outline of the body within.

8. Pick off all the feathers of a pige or hen and weigh them.

What is their weight? What fraction is this of the weight of the entire bird?

Use Jordan's *Manual of the Vertebrates* for finding the names of our native birds.

HOW TO PREPARE A BIRD SKIN.

Materials Needed. — 1. A freshly killed bird, in good condition. 2. Arsenic, or arsenic and powdered alum in equal parts. 3. Cotton. 4. Several sheets of paper; stiffer paper than newspaper is preferred. 5. A plate. 6. Scissors. 7. Knife (scalpel, if possible). 8. Forceps. 9. String. 10. Corn meal, to sprinkle on for absorbing blood or other liquid escaping.

Process. — First make a wad of cotton and with the forceps push it into the throat. This is to keep moisture from escaping and soiling the feathers. Do the same with the anal opening. Break both wings as close to the body as possible. Now lay the bird on its back, with the head toward your left. Part the feathers along the breast and abdomen. Hold them apart with the thumb and fingers of the left hand, while with the scalpel you cut through the skin, beginning at the center of the breast and going straight back to the anus. Here make a fork in the cut and go around the anal opening. With forceps hold up the edge of the skin while loosening it with the handle of the scalpel. Be careful during the whole process to keep the feathers turned back so they will not be soiled by coming in contact with moist tissues. Sprinkle with corn meal to absorb moisture. Loosen the skin on one side down to the thigh, and around the knee. Then with the thumb and finger take hold of the tarso-metatarsal joint (heel) and push the knee out, at the same time pressing the skin back so as to expose the knee. Run one blade of the scissors under the bend of the knee and cut through the joint (cut close to the joint of the scissors to avoid straining them). Cut through the remaining flesh, being careful not to cut the skin. Take hold of the leg with thumb and fingers of one hand, thus suspending the whole body. With the thumb and fingers of the other hand carefully scrape the skin away from

the flesh, using the thumb and finger nails. It will not do to pull on the skin, as it is too tender. On reaching the heel remove all the flesh, leaving the bone. Now pour about half a teacupful of arsenic on a plate. Hold the everted leg over the plate and apply arsenic thoroughly to the skin and the bone. Take hold of the toes and pull the skin right side out again. Repeat this with the other side. After loosening the skin well back on the sides, lift the bird, rest the front end of the breast on the table, and turn the tail toward the back. Cut through the bones supporting the tail close to the bases of the tail feathers, but care must be taken not to loosen them. Over the rump there is almost no flesh and the skin adheres to the bone. Especial care must be taken here not to tear the skin.

Continue toward the head, turning the skin wrong side out. From this point on, it is very convenient to have a suspended hook by which to hang the bird so you can use both hands in skinning. Otherwise hold the body just in front of the hips. If pressure is applied to the abdomen its soft contents may be forced out. When the shoulders are reached, skin as far as the elbow and cut off the wings where the bones were broken. When the head is reached great care must be exercised. Proceed slowly, pressing the skin loose with the nails. At the ear, the thin sac, lining the ear down to the drum, must be pulled out. In skinning past the eyes be sure not to cut the eyelids. Continue to the base of the bill. Sever the neck close to the skull, cut out the base of the skull and remove the brain by scooping it out with the handle of the scalpel. Remove the eyes, tongue, and all soft tissues on the head. Now return to the wings and cut away all the muscle from the humerus. It is not safe to try to skin beyond the elbow because it would loosen the secondaries; but the fleshy inner surface of the forearm may be uncovered, part of the muscle removed, and arsenic pushed in to poison what remains. Remove any particles of muscle or fat still adhering to the skin. Now lay the skin, still turned inside out, on the plate of arsenic. Roll it over and over in the arsenic and thoroughly rub the preservative on every part of the skin, skull, and other bones, especially at the wings, legs,

and tail. Roll balls of cotton and place in the eye sockets. Now proceed to turn the skin. Placing the thumbs at the base of the skull, use as many fingers as can work in pulling (or rather rolling) the skin back over the head, the thumbs meanwhile pushing. Care and *patience* must be used here, otherwise a good skin may be ruined. When the skin has been turned back over the head it is easy to grasp the bill, and the entire skin is again outside out. It will probably look rather dilapidated, but do not be discouraged. Shake it, holding by the bill, to get rid of the loose powder and to rearrange the feathers. With forceps or scalpel handle arrange the feathers where needed. Lay the skin on its back. Make a slender roll of cotton for a neck, and with the forceps insert it so it will reach the base of the skull. Next make a body of cotton (you have the model before you). In inserting the body, see that the feathers around the edge of the cut are not turned in. Draw together the edges of the ventral cut; it is not necessary to sew, but the feathers should be made to overlap naturally. Cross the feet and tie them together, thus crossed. Make a stiff paper cylinder, and tie or pin it so it will not spread. Slip the skin in, head first of course, taking care that the feathers overlap properly. Especial attention needs to be paid to the region of the shoulders. Attach a label, with the name of the bird, sex, date, locality, and your name. Lay away in a safe, dry place for at least a week, before removing from the cylinder. Birds may be mounted on a board with wings spread.

DISSECTION OF THE PIGEON.

In dissecting the pigeon place it on a smooth board about twelve inches wide and eighteen inches long. If a sheet of paper be fastened to the board by thumb tacks, the board may be kept clean for repeated use. In dissecting it is better to turn the board than to turn the specimen on the board. The wings and legs or any flaps of muscle may be stretched out and tacked down to suit convenience at different stages of the work.

Pluck the pigeon before dissecting it; dipping the bird in hot water makes this easier.

1. Insert a large tube into the mouth and inflate the **crop**, compressing the neck to prevent the escape of the air. Note the shape of the crop.

2. Beginning at the posterior end of the breastbone, cut through the skin along the line of the ridge, or keel, of this bone, and loosen the skin on each side, continuing forward over the crop, being careful not to tear the crop; again inflate the crop, and examine it more fully. Observe the fine lines running crosswise and lengthwise in the walls of the crop; these are the **muscle fibers**, transverse and longitudinal.

3. Loosen the crop from the front of the breast and from the neck. Find the windpipe, or **trachea**, with its white rings of cartilage.

4. On each side of the neck is the **jugular vein**. If it does not show distinctly, let the bird's head and neck hang over the edge of the table, and the vein will soon fill with blood.

5. Close to the jugular vein is a white cord, the **vagus nerve.**

6. Insert the tube into the glottis, and inflate; observe the swelling of the whole body, and the inflation of the thin-walled **air sacs** in the hollow in front of the breastbone.

7. Break the bone of the upper arm, the **humerus**; cut through the skin and muscles, and push out through this opening the end of the bone next to the body; note that it is hollow; slip one end of a rubber tube over the end of the bone, and inflate; what is the result of this experiment? Keeping another tube connected with the windpipe, determine whether air can be sent in through the windpipe and out of the humerus, and *vice versa*.

8. Slit the skin back over the abdomen to the anus, loosen it well back on each side, and cut through the abdominal wall just behind the breastbone; inflate once more, and observe the **abdominal air sacs.**

9. Cut down into the muscle of the breast, close alongside the ridge (keel) of the breastbone, and around the outer border of the breastbone; thus loosen and raise a great flap of muscle, **the pectoralis major**. Note the nerve and blood tubes entering

its inner surface; separate it from a smaller muscle lying under it, which will be known by the glistening appearance of the muscle sheath; sever the attachment of the pectoralis major to the breastbone, and all other organs except at the extreme front end; here the muscle narrows into a tough white cord, or **tendon**; trace this tendon to its attachment to the bone of the arm; now lay the pigeon on its back in one hand, and pull this muscle backward, noting the effect on the wing. In like manner loosen all the posterior attachments of the **subclavian** muscle which was covered by the pectoralis major, lying in the angle between the keel of the breastbone and the body of the breastbone; prove its action, this time holding the pigeon right side up. Compare these two muscles in size, and in the amount of work they have to do. The hinder attachment of each of these muscles is called its **origin**; and the place of attachment of the tendon to the wing bone is the **insertion**. Cut through the body wall around the margin of the breastbone, through the ribs, coracoid bones, and wishbone, and entirely remove the breastbone.

10. Covering a considerable part of the abdominal organs is the reddish brown **liver**.

11. Lift the liver and disclose, at the left of the body cavity, a hard mass, the **gizzard**. Slit the abdominal wall in the middle line back to the anus, push aside any fat that may cover the internal organs, and turn the gizzard to the left of the bird to find where the intestine arises from it; trace the intestine from the gizzard backward.

12. The part of the intestine nearest to the gizzard is the **duodenum**.

13. In a long loop formed by the duodenum is a pinkish organ, the **pancreas**.

14. Trace the intestine, tearing away the fat and the thin walls of the abdominal air sacs, observing that it is held in place by a thin, transparent membrane, the **mesentery**.

15. The intestine has two short side branches, the **ceca**.

16. Just before the intestine ends, it widens, forming **the cloaca.**

17. Turn the gizzard to the right of the bird; entering it from the front, find a mottled, bulging tube, the **glandular stomach**; pull the crop forward, to shew the connection between it and the glandular stomach. To the right of the glandular stomach is the small, red spleen; pull the gizzard backward, and cut off the glandular stomach as far forward as possible; remove the gizzard and intestines. Note the relations of the tubes which enter and leave the gizzard; open the gizzard, observing the thick outer muscular coat, from which the gizzard is sometimes called the **muscular stomach**. Note also its tough lining; examine the contents of the gizzard; why does the gizzard have such a thick coat of muscle? Do all birds have this kind of gizzard?

18. In front of the liver is the **heart**, in a thin sac, the **pericardium.** Cut into its posterior wall, and turn the heart forward, to see the dark vein, the **postcaval vein**, running to it from the liver; pull the heart backward, to see the whitish **arteries** running forward from it. The main artery runs forward, and turns to the right before going backward, while in man the corresponding artery turns to the left. Prick a hole in one of the large veins near the heart; insert the point of a blowpipe, and inflate the heart; its red, conical part is composed of the **ventricles**; the dark base is made up of the two **auricles.** Tie a thread around the veins at the anterior and posterior borders of the liver, and cut this organ away.

19. On each side are the pink lungs. Pick away the thin membranes bordering the outer hinder borders of the lungs; look for holes through which the lungs communicate with the abdominal air sacs; look for the trachea. Remove the lungs, not failing to see how closely they are attached to the back, being indented by the ribs.

20. In the hinder part of the body cavity are the dark-colored, irregular **kidneys.** Tear them away, observing how

they are composed of several lobes, which fit into the hollows of the **pelvis**. After removing the kidneys, observe the white nerves extending outward from the sides of the spinal column to pass to the thighs.

21. In front of the kidneys are the two white oval **spermaries**, in the male; in the female, the **ovary**, often showing many eggs in different stages of development. The kidneys and reproductive organs send tubes to the cloaca; the tube which conveys the eggs from the ovary to the cloaca is the **oviduct**.

22. Remove the heart, cut off the auricles, and look down into the ventricles; cut across the middle of the ventricles, and make a drawing of this cross section.

23. Observe the fold of skin extending across the angle between the arm and forearm; dissect away the skin, and find a membrane within the skin fold.

24. Observe the muscles connecting the hinder edge of the breastbone and the pelvis (which were cut through in opening the abdomen); these are the abdominal muscles. How does the bird perform the act of breathing? Compare the bird, snake, frog, and man, in their modes of breathing.

25. Bend the leg up close to the body, to the position of perching; what effect does this bending of the leg have on the toes? How does the bird stay securely on the perch when asleep? Dissect the leg to find the mechanism by which the toes are clenched as the leg is bent.

26. Dissect out the tongue, and compare it with the tongue of the snake.

27. Clean away as much as possible of the soft tissues, and keep the skeleton for later study.

THE BRAIN OF THE PIGEON.

Cut away the top of the skull with a sharp knife, using great care not to injure the soft brain, and make out the following parts: —

1. In front, the large **cerebrum**, consisting of two **hemispheres**, which are separated by a deep groove.

2. Behind the cerebrum is the undivided **cerebellum.**

3. Running backward from the under side of the cerebellum is the **spinal cord**; trace it back into the backbone. Make drawings of the brain, as seen from above and as seen from the side.

THE SKELETON OF THE PIGEON.

Notice the lightness of the whole skeleton. What part of the pigeon's weight is bone? Compare the eye cavity with that of man. The lower jaw does not join the skull directly, as in man, but is joined to an irregular bone, which, in turn, joins the skull. This is the **quadrate bone**. The hole by which the spinal cord leaves the brain cavity is the **occipital foramen**; in front of this foramen is a little, rounded projection, the **occipital condyle.** Observe how this condyle fits into a cavity in the first vertebra of the neck. Count the vertebræ of the neck, or **cervical vertebræ.** Observe the consolidation of the vertebræ in the back; note the joint in each rib, and the arrangement for bracing the ribs together. Press the breastbone alternately toward the back and away from it, meanwhile watching the joints in the ribs.

The "wishbone" corresponds to the two "collar bones" of man. Alongside the two branches of the wishbone are the coracoid bones; what especial need of such bones in this place? In the wing find, in the arm, the **humerus**; in the forearm, the **ulna** and **radius.** The **hand** has only part of the fingers developed; a little bone, representing the thumb, is present (which bore the feathers of the "false wing"). In the thigh is the **femur**; in the leg is the **tibia**; and alongside it, the small **fibula.** The bone above the foot represents the consolidated bones of the human ankle and foot as far as the toes. What evidence is there of such consolidation?

THE HEN'S EGG.

So place a hen's egg in a basin of water that it cannot roll, mark the upper side plainly, and boil it hard; keep track of the side that was uppermost.

1. Crack the shell, and pick it away; put a piece of it in strong vinegar, or other acid. Of what is the shell made?

2. Note the thin membrane lining the shell.

3. Does the egg completely fill the shell? Where is the **air space**? Does the lining membrane, in this region, adhere to the shell or to the "white"? How can a fresh egg be distinguished, without breaking? Does a fresh egg, in water, lie in the same position as when on a table? What is the use of this air space?

4. How is the yolk situated in the white? How in reference to the position during boiling? Compare a number of eggs, to see if there is any regularity about this.

5. Note the round spot on the yolk, where it comes nearest to the surface. This is the **germ spot**, in which the chick begins to form.

6. With a sharp knife, split the egg lengthwise. Is the white alike throughout? Is the yolk alike throughout? Has the yolk a coat? Cut and tear these parts to make out their structure, if they have any definite structure.

7. Boil an egg hard, as before; mark a line lengthwise around the egg, passing through the point that was uppermost while boiling; carefully break away the shell on one side, and with a clean cut remove this half of the white and yolk; place the other half in the position it had while cooking; make a drawing of this section, using different colors to show the shell, shell membrane, air space, white, yolk, germ spot, etc.

8. Prop an egg on end, and boil in this position. Is the yolk in a different position in consequence? The white of the egg has interlacing fibers and partitions which keep the mass together; the white cannot be mixed with water till these membranes are cut or broken; hence an egg, to be eaten raw, should be whipped to break these membranes. The white is not a part of the true egg. In dissecting a bird, the eggs, of various sizes, according to their stages of development, may be found in the ovary. At this time the egg consists of the yolk, with a thin coat; the white is deposited around this later, during its descent through the oviduct;

the shell is last formed, and is absent in the case of most animals. In the development of birds all their nourishment, before hatching, must be stored in the egg; hence its large size.

9. Set a hen on a dozen eggs; mark the date; open and examine an egg each day; if the egg was fertilized, the cells of the germ spot multiply by division, and soon take definite arrangement; at the end of twenty-four hours the backbone is outlined; during the second day the brain begins to develop, and the heart appears; on the fourth day the legs and wings make their appearance as flattened buds; during the first few days it is hard to say whether the embryo was that of a bird, a reptile, or a mammal; after this, the characters peculiar to birds become evident, the feathers begin to develop, and, later, the particular kind of bird may be recognized.

Egg-laying animals are called **oviparous**. If the young develop within the body of the parent, receiving nourishment from the blood of the parent, the animal is said to be **viviparous**; "or, the young may complete its development while the egg remains in the interior of the body of the parent, but quite free and unconnected with it, as in those vertebrates which are termed **ovoviviparous**."

The study of **development** is called **embryology**.

Topics for Reports. — Ostrich Farming. Origin of our Domestic Fowls. Origin of the Domestic Pigeon. Varieties of Pigeons. Game Birds. The Guinea Fowl. The Turkey. Hawking. Carrion-eating Birds. Birds whose Plumage is used for Ornament. Birds and Millinery. Laws for Bird Protection. History of the English Sparrow. The "American" Eagle. The Fishhawk. The Whip-poor-will. Introduction of New Game Birds. The Road Runner. The Mocking Bird. The Water Ouzel. Hawks and Owls.

Read *American Natural History*, Hornaday.

CHAPTER XII.

MAMMALIA.

THE RABBIT.

Field Study.

1. **Learn** where to look for rabbits at different seasons. Keep in mind that they are timid creatures and seek shelter, and that they prefer to be near a good supply of food.

2. In what kind of places are rabbits usually found in warm weather? Look in tufts of grass along hedges and fence corners. Do rabbits seek more sheltered places in winter? Is this on account of cold? Or for concealment? The smoothed and sometimes slightly hollowed place in which a rabbit squats is called its "form." Is this form equally exposed on all sides? Can it enter and leave in any direction? Has the direction in which it is headed any relation to the wind? In what position does it rest? Are the ears erect or laid back while it sits in its form? Does a rabbit leave its form in the daytime, if undisturbed? Does it sleep during the day? Are the eyes open or shut while it sits in its form in daytime? As you quietly approach the rabbit squatting in its form, does it seem aware of your presence? Does it ever turn the head to see you? Does it need to turn the head to see you? Can a squatting rabbit see an object in any direction without turning its head? Stand near a rabbit in its form and watch its eye. Does it wink? How much of the time is a rabbit in its form? How much of the time out of it? Find a rabbit in your neighborhood and frequently visit it to become as well acquainted with it as possible. On moonlight nights visit a form that you have lately

found occupied. Is "Brer Rabbit" at home? Are rabbits sociable? Do they associate with each other more at one season than at another? Do they seem to have any special means of communicating with each other? Do they ever give signals of danger? Does one ever call another to share food that it has found? Do they ever aid each other in any danger or injury? Has the rabbit a voice? If so, on what occasions is it used? How do rabbits protect themselves from cold? How does the squatting position economize heat? Do rabbits ever stretch out and lie at full length? Or are they always bunched up when resting? In what situations do you find rabbits in warm weather? In very cold weather? In dry weather? After heavy rains? Do rabbits ever burrow? Do they hide in holes? What are the effects of substituting barbed wire fences for rail fences and hedges? What is the effect of grubbing out bushes in clearing land for cultivation? How does the cultivation of farm and garden crops affect rabbits? Is the number of rabbits ordinarily increased or diminished in "settled" districts?

3. Study carefully the rabbit's modes of locomotion, the slow hopping as well as the running. Study the tracks and be sure you can tell by which foot each track is made, and how the legs are moved. Can you tell by the tracks whether or not the rabbit was frightened? How far can a rabbit jump? Are the front and hind tracks farther apart when running than when hopping? Can a rabbit run far without stopping? Follow a frightened rabbit; does it run far in a straight line? Can you stop a running rabbit by whistling? Do rabbits ever zigzag when running away? If so, why? Are rabbits long-winded? Compare a rabbit and a greyhound in this respect. What reasons for the difference? Can a rabbit swim? Does it often take to water?

4. What evidences do you find in fields and among bushes as to the rabbit's food? When does it eat? Does it need much or little food? Does it usually go far from its form for food?

Does the kind of food vary much with the season? Does it need to make much effort to get its food? Do rabbits drink water? Look along creeks and around springs for evidences of their visits. Is it clear that they come to such places to drink? Does the amount of water in their food make any difference in the amount of water that they take as such? Do they need the same amount of water at different seasons? What reasons for these differences? Do they ever suffer for water in severe winter weather, when streams are frozen over?

5. What harm is done by rabbits? Do they do any good? What means are employed to keep them from doing damage? What means to kill them off?

6. What are the enemies of rabbits? In what different ways do they avoid or escape enemies? Is there any advantage in having the exposed part of the tail so white and conspicuous? What kind of shelter does a rabbit seem to prefer when pursued by dogs? Do rabbits ever "double" on their tracks? Or resort to other tricks to escape pursuit? What is meant by "circling"?

7. In spring and early summer look for the nests containing young rabbits. They are not conspicuous, being pocketlike depressions lined with fur, and narrowed at the opening, which is at the level of the surface. If a nest is found, watch it closely day and night. If you have a dog, be careful not to allow him to accompany you, for even if he does not disturb the nest while with you, he may return and kill the young. Does the mother stay with the young? If not, does she remain near? When and how often does she visit the young, and how long does she stay with them? Do rabbits have more than one litter in a year? How many in a litter? Is their natural rate of increase slow or rapid as compared with most mammals? Are the young of the same color as the adults? Are there any peculiar markings? How long does it take a young rabbit to reach full size? Are young rabbits as speedy or as cunning in escaping enemies as the old ones?

HOME STUDY OF RABBITS.

1. For this study use a wild rabbit caged, a tame rabbit, or a Belgian hare. Study many of the points to which attention has been called in the suggestions for the study of wild rabbits in their homes, such as the modes of hopping, jumping, running, modes of moving the feet, the tracks, etc. Study also the various attitudes of rest and motion, of timidity, of effort at concealment, of hunger, the use of the ears and eyes. Do they give any signals when alarmed? Do tame rabbits recognize dogs as enemies? After an alarm do rabbits soon become quiet, or does fright have a more lasting effect? Has a rabbit any means of defense against enemies? Are the claws ever used when it is attacked by a dog? Or when it is seized by a man, as when pulled out of a brush heap or a hole? Do rabbits ever fight each other?

2. Find what food the rabbits prefer. Does a rabbit eat much, relatively? Does it eat rapidly or slowly? Watch the process of eating. How do the jaws move? What is the use of the "harelip"? If possible, in this connection, get a well-cleaned rabbit's skull, and study the teeth and the hinge by which the jaw joins the skull. Why is there a vacant space between the gnawing teeth and the grinding teeth? How are the front teeth kept sharp? How do the ridges run on the grinding surfaces of the back teeth? Why is this so?

3. Is a rabbit's eye large or small, in proportion to its size? Is its sense of sight keen? Test this in various ways. What is the shape of the pupil of the eye? Is it relatively large or small? Does it vary with the amount of light? Do you ever see color in the pupil? If so, in what situations? Is the iris of the same color in all rabbits? Compare wild and tame rabbits in this respect. Test a rabbit's sense of hearing. Is the fact that a wild rabbit often sits motionless in its form, sometimes till actually kicked out, any proof that it did not hear or see the hunter? What is it probably thinking in such a situation?

Test the sense of smell in rabbits. Does it use this sense in judging food? Has it a keen sense of taste? Try to test the sense of taste without also bringing into use the sense of smell. Test the sense of touch. What is the use of the "whiskers"? Do you think a rabbit possesses any sense that you do not have, or lacks any that you have?

4. Are rabbits cleanly in their habits? Do they wash their paws and faces as do cats? Do rabbits shed hair? Do they change their color during the year? Do rabbits have parasites? If so, what kinds? Do they do anything to get rid of them? Can you do anything for such troubles? Are rabbits especially subject to any diseases? If so, what are they, and what can you do to prevent disease, or to cure it if it has become established?

EXTERNAL FEATURES OF THE RABBIT.

1. Note the shape and proportions of the body. The anterior part of the body, distinguished by the ribs, is the **chest**, or **thorax**; the soft-walled, posterior part is the **abdomen**. Note the relative size of the fore and hind limbs. Are the soles of the feet bare or hairy? How many toes has each foot? Are there claws? Are they weak or strong? How do they differ from those of a cat? In the hind limb how much belongs to the foot?

2. How many kinds of hair do you find on a rabbit? The short hairs, making the most of the coat, are the **fur**. How do the hairs of the fur differ from the other hairs? Press hair and fur aside till you can see the skin; is the color the same in the deeper parts as near the outside? Pull out hairs of different sorts; has an individual hair the same color from end to end? Are the different hairs of the same thickness and strength? Are they all rooted to the same depth in the skin? Are the hairs glossy or dull-surfaced? Do they seem oily? Do they become wet easily? Compare them with the hairs of a mink or muskrat in these respects. Examine different hairs under a microscope.

What are the qualities that make some kinds of hair or fur preferable to others for making furs, felts, and fabrics? What are some of the chief articles made of fur after it is separated from the skin?

3. Examine the eyes and eyelids. Can you find a third eyelid? Is it useful?

4. Examine the mouth. What is the use of the "hare-lip"? What is the shape of the nostrils? Look closely at the inside of the cheek. How many front teeth are there and how are they arranged? Are they alike in size and color? Have any of them any peculiar markings? Examine the tongue and palate.

5. Examine the ears. Hold one of them up toward a good light.

6. Examine the tail. What is its usual position? Can you make it stay in any other position? Is its color uniform? Of what use is it?

Use Jordan's *Manual of the Vertebrates* in finding the names of all the mammals met with in your neighborhood.

DISSECTION OF THE RABBIT.

The rabbit should be dissected on a board eighteen inches long by twelve inches wide. This should be covered with heavy manilla or straw paper, fastened down by tacks. The specimen should be a freshly killed, uninjured one, those obtained from the markets being usually so mutilated as to be unfit for this work.

1. Lay the rabbit on its back, stretch out the front and hind limbs and tack firmly through the feet. Slit the skin in the middle line from the base of the neck to the pelvis and strip it well back along the sides. Compare the walls of the thorax and abdomen. With forceps pinch up a fold of the wall of the abdomen, and with scissors cut through the wall in the middle line. In all this work be careful that the lower point of the scissors does not injure anything within. Cut forward in the middle line to the breastbone.

When the chest is first opened, look in to see the position of the heart. The attachment along the inside of the breastbone must be cut close to the bone.

When the breastbone is reached, let the cut fork to each side along the line where the bony part of the ribs ends and the cartilaginous part begins. At the anterior end cut across the breastbone and entirely remove it. Extend the slit in the abdominal wall to the pelvis. Make slits outward in the middle of each side of the abdominal wall; turn the flaps outward, pinning them down if necessary. There are now disclosed the two parts of the **body cavity**, the **chest cavity**, or **thoracic cavity**, containing the heart and lungs, and the **abdominal cavity**, containing the digestive organs. Between these two cavities, and the sole partition separating them, is the thin muscular **diaphragm**. Examine the diaphragm from the anterior side. Can you see that its central part is thin and nearly transparent? This is the tendinous part of the diaphragm. Note the shape of the diaphragm as seen from the front. Gently press the liver backward to see the posterior surface of the diaphragm. Take hold of the diaphragm with thumb and finger on its opposite surfaces to learn its thinness, its smoothness and flexibility. Is the diaphragm flat or arched? How is it arched?

The Organs of the Abdominal Cavity.

1. Observe that the ventral wall of the abdomen is composed of muscle. Its smooth lining is the **peritoneum**. Feel of it.

2. Study the abdominal organs in their natural position. Filling most of the space of the abdominal cavity is the coiled intestine; next to the diaphragm is the dark-colored liver; back of the liver, and partly covered by it, is the stomach; and in the posterior part of the abdomen is the bladder.

3. Pull the intestine backward, and make out the shape, size, position, and color of the **stomach**. Observe how the liver and stomach fit together; push the liver forward, and turn the stomach back to find a white tube entering its anterior surface;

this is the gullet, or **esophagus**. Just back of the stomach is a small, red body, the **spleen**.

4. Find now the connection between the stomach and intestine. Make a drawing of the stomach, showing its shape and the connections with the gullet and intestine.

5. Trace the intestine; that part which forms a long loop near the stomach is the **duodenum**. Within this loop is an irregular, fatty-looking mass, the **pancreas**. Find the **pancreatic duct** entering the intestine. This is more easily found in the dog.

6. Observe that the intestine is held by a thin membrane in which are branching blood tubes, this is the **mesentery**; find its supporting attachment. In tracing its course drag the intestine out of the abdominal cavity, but do not tear the mesentery.

7. The large, greenish side branch of the intestine is the **cecum**. All the intestine from the stomach to the entrance of the cecum is the **small intestine**; that part of the intestine posterior to the entrance of the cecum is the **large intestine**.

8. In handling the liver remember that it is very delicate and easily torn, also that it contains much blood, and if torn is likely to bleed enough to interfere with the dissection. Do not touch the liver with any sharp instrument; even the finger nails may tear it unless one is careful. Pull back the liver to see how snugly it fits against the diaphragm. Are the two attached to each other? Note the divisions, or **lobes**, of the liver. Tip the liver up and forward to see the stomach, and how the organs fit each other. On the posterior surface of the liver find the dark **bile sac**. If its duct to the intestine is not readily seen, press on the sac and some of the bile may be forced along the tube, thus showing its course. Later snip a small hole in the bile duct, insert a bristle tipped with sealing wax, and find where the duct enters the intestine.

9. Tie the gullet in two places half an inch apart and cut through between them. Do the same with the hinder part of the

large intestine, the **rectum**, and sever it. Remove the stomach and intestines, carefully cutting the mesentery along its whole attachment to the intestine, and uncoil the latter. How many times is the length of the body, including the head, contained in the length of the intestine? Compare the lengths of the small intestine, cecum, and large intestine. Cut out about an inch of the small intestine in the middle of its course, slit it open lengthwise, wash it thoroughly, and examine, under water, its inner surface with a lens, to see the threadlike projections, or **villi**. In the same way examine a piece of the large intestine. These points may be made out in the intestine of a dog, or from specimens of the calf's intestine obtained from the butcher. Tie the postcaval vein just in front of the diaphragm and just back of the liver; cut away and remove the liver.

10. Observe the two bean-shaped kidneys attached to the dorsal wall of the abdomen. They are covered by a thin layer of membrane, the peritoneum, which lines the whole of the abdominal cavity, and turns downward to form the mesentery, which, like a sling, holds the intestine in place; the mesentery also covers, and almost completely surrounds, the stomach as well as the liver. An artery, a branch of the aorta, extends into each kidney, and from each kidney there runs a vein to join the large postcaval vein. There is also a tube, the **ureter**, from each kidney, running back to the urinary bladder.

The Heart and Lungs in Natural Position.

1. It should be noted that the heart and lungs collapse when the chest is opened, and that they do not now show their natural size. Slit the skin along the middle of the throat and find the windpipe. Cut a slit in it lengthwise. Insert a tube, connected by rubber tubing with a pair of bellows; or inflate by the breath. The lungs may be swelled to their natural size, filling the chest. This will also show the natural relations of the heart and lungs. Note how the lungs nearly surround the heart. Compare the

color of the lungs when inflated with the color when collapsed. Notice the subdivisions, or **lobes**, of the lungs.

2. In another rabbit, later, open the abdominal cavity without injuring the thorax. Pull back the liver, and the pink lungs will show through the thin central part of the diaphragm. Keeping the eye fixed on the lung, prick a hole through the diaphragm near one side, and note the collapse of the lung. Is the lung of the other side affected by this operation? Open the chest and note the thin partition separating the two sides of the chest. This partition, the **mediastinum**, is a double membrane, and the heart lies between its two layers. The following study of the heart and lungs may be made with the heart and lungs of one rabbit; but if the same organs of a pig, sheep, or calf can be obtained, it will be better to use them on account of their greater size.

Topics for Reports. — The Fur-bearing Animals, such as the Beaver, Otter, Sable, Mink, Muskrat, etc., with Accounts of their Homes, Habits, and the Modes of trapping them. The Hudson Bay Company. The Native Ruminants of North America, such as the Musk Ox, Caribou, Moose, Elk, Deer, Sheep, Goats, and Antelope. The Kinds of Bears native to North America. The Mountain Lion. The Coyote. The Timber Wolf. The Wild Cats. Prairie Dogs. The Weasel. The Badger. Jack Rabbits. Porcupines. The Buffalo.

Read *American Natural History*, Hornaday.

CHAPTER XIII.

MAMMALIA (*Continued*).

DISSECTION OF THE HEART AND LUNGS.

THE heart and lungs of a sheep, pig, or calf are better to study on account of their greater size.

1. Hold up the mass by the windpipe, with the heart away from you. The end now uppermost is the **anterior** end, that below is the **posterior** end; the lung to your right is the **right** lung, the one to your left is the **left** lung; the surface nearest you is the **dorsal surface**, and that opposite is the **ventral surface**.

2. Observe the windpipe, or **trachea**, with the stiff rings of gristle, or **cartilage**. The thick part of the anterior end is the **larynx.**

3. Running along the dorsal surface of the windpipe is a soft red tube, the **gullet** or **esophagus**. At about the middle of the windpipe separate the gullet and windpipe for three or four inches. Note that next to the gullet the windpipe is soft and yielding, where the gaps of the C-shaped cartilages are filled with muscular and elastic tissue. Make a slit two inches long in this soft membrane.

4. Inflate the lungs as follows: Take a wooden faucet, slip the small end of the faucet into the slit just made in the windpipe, and hold or tie firmly, but do not cut off either gullet or windpipe. Inflate through the spout, then shut off the air; if the lungs have not been punctured they should now remain distended. In holding up the lungs, *take hold of the windpipe* above where *the faucet* enters, and hold in such a way as to pull the windpipe up and at the same time press the faucet down. If this is done, it will not be necessary to tie the faucet in. Note

(*a*) the conical shape of the whole; compare this with the chest cavity, as shown in a skeleton; (*b*) how the lungs nearly surround the heart; (*c*) the concave posterior surface of the lungs where they fitted the convex anterior surface of the diaphragm; (*d*) the groove between the dorsal surfaces of the lungs in which the spinal column fitted; (*e*) the smooth, undivided dorsal surface of the lungs, and their division ventrally into **lobes**; (*f*) the relative lengths of the dorsal and ventral surfaces of the lungs. The anterior end of the lung is the **apex**; the posterior end is the **base**. Open the valve of the faucet. What makes the air go out? Again inflate. Does it require effort to do so? Why? Cut off the end of one lobe and again inflate. Does the air escape? Throw a piece of lung on water. Pinch a piece of lung, holding it near the ear. The smooth, moist, glistening membrane covering the lung is the **pleura**.

5. Observe a large whitish or yellowish tube running in the groove between the dorsal surfaces of the two lungs. It is usually covered with fat. It may have been cut off short, so that its open end is easily seen near the windpipe. This is the main artery, the **aorta**. Take hold of its free end and separate it from its attachment to the other tissues, cutting close to it with the scissors, so far as where it arches over the root of the left lung. Now turn the free end forward.

6. Find where the gullet is cut off posteriorly; slit it open for an inch or two, and note its whitish lining, the **mucous coat**. The thick red coat is the **muscular coat**; it has an inner layer of circularly arranged muscular fibers and an outer longitudinal layer. Beginning posteriorly, separate the gullet from the windpipe, cut off the windpipe about the middle, and entirely remove the gullet and larynx.

7. Examine the windpipe; insert a finger, and stretch it; note its C-shaped cartilages. Its lining is a **mucous membrane**.

8. Lay the heart and lungs on their ventral surface, with the posterior end near you. Using the handle of the scalpel as a chisel, clear away any tissue covering the windpipe, and trace it

to the lungs; its branches are the **bronchi**. How many bronchi are there? Here are often found small, oval, brownish masses, the **lymphatic glands**, embedded in connective tissues. Scrape these loose with the scalpel handle.

9. Lay the lungs on their dorsal surface, with the anterior ends toward you. Note how easily the heart may be moved about in its case, the **pericardium**. Slit the pericardium along its ventral side, and note the smoothness of its lining and of the surface of the heart. Observe the **pericardial fluid**.

10. Carefully compare the right and left sides of the heart. Running obliquely across the surface of the heart is a groove in which are blood tubes, often covered with fat. The part at the right of the groove is the **right ventricle**; at the left is the **left ventricle**.

11. At the base (anterior end) of the heart on each side are the right and left **auricles**.

12. Tip up and toward you the apex of the heart. Compare its width and thickness; compare the ventral and dorsal surfaces as to length, convexity, etc. Press the two ventricles, and compare them in firmness.

13. Turn the heart to the left, and examine the right auricle; find a large, flabby, red tube entering its anterior surface, the **precaval vein**. Prick a small hole in it, and insert the blowpipe; hold firmly around the opening and inflate. This shows the outline of the right auricle. Meanwhile, watch closely the dorsal part of the auricle; the **postcaval vein** should now be discovered entering the auricle from the posterior region. Look for it outside, and on the dorsal side of the pericardium, where it runs anteriorly from the diaphragm.

14. Turn the heart to the right, and observe a large, light-colored tube arising from the base of the right ventricle between the two auricles; this is the **pulmonary artery**. Again turn the heart to the left, and raise the right auricle; find the **aorta** arising from the center of the base of the heart. Carefully separate the aorta from the pulmonary artery, and trace

it as it arches over the left bronchus and runs down between the two lungs by the side of the gullet. Clear away any fat or other tissue adhering to it.

15. From the arch of the aorta arise the branches running to the head and fore limbs.

16. In the same way trace and clear the pulmonary artery.

17. When the fork of the pulmonary artery has been reached, lay the heart and lungs on their ventral surfaces, with the posterior end toward you; turn the windpipe back toward you, and with the scalpel handle trace the branches of the pulmonary artery into the lungs. Cut them off close to the lungs.

18. Keeping the parts in the same position, trace the **pulmonary veins.** These are to be found on the ventral side of the bronchi; their general outlines may be shown by inflating as follows: Cut off the first branch of the aorta as close as possible to the arch. Insert one blade of the scissors in this opening, pointing *away* from the heart, and make a slit two inches long. Insert a cork toward the heart. It should fit snugly, so that air may not escape. For a pig's heart a cork three fourths of an inch in diameter at its larger end is about right. Make a very small hole in the tip of the left auricle, insert the blowpipe, holding firmly around it, and inflate. This should distend the left auricle and the pulmonary veins. With the handle of the scalpel scrape away fat or connective tissue that covers them, and trace them to the left auricle. How many are there? Cut off the left bronchus close to the lung, and turn the windpipe to the right. Clear the pulmonary veins from any tissue that lies under them. Turn now to the ventral surface of the heart; lift the ventral margin of the flap of the left auricle, and with scissors cut into the left auricle through the bottom of the groove between the left auricle and the left ventricle. Make a slit an inch long, following the groove. Pass a probe into the opening, then directly across the cavity of the auricle, to the dorsal wall of the auricle. Here are the entrances of the veins from the right

and left lungs. Use the finger as a probe, enlarging the opening a little if necessary. Cut off the pulmonary veins near the lungs, cautiously avoiding other blood tubes; trim away the pericardium. If the preceding work is interrupted at about this point, wrap the heart in paper; write your name upon the wrapper, and keep the heart in a cool place for later study.

19. With the scissors slit down one bronchus into the lung, noting its branches. Follow the outside of another bronchus, tearing away the lung tissue with the scalpel handle.

Structure and Action of the Heart. — 1. Briefly review: precaval vein; postcaval vein; right auricle; right ventricle; pulmonary artery; pulmonary veins; left auricle; left ventricle; aorta. Hold the heart suspended by the end of the aorta, and dance it up and down to show the elasticity of the aorta. Cut off the aorta where the slit was made at the arch, and feel the inner surface.

2. Run a probe into the precaval vein, through the right auricle, and out of the postcaval vein. Cut along the upper side of the probe, and explore the cavity of the right auricle. Feel the inside of the auricle and veins. Observe that the cavity of the auricle extends farther into the heart than the notch between the auricle and ventricle. At the extreme left of the right auricle is the mouth of the **cardiac** (coronary) **vein**, which, running around between the left auricle and left ventricle, brings blood from the ventral walls of the heart. Near the mouth of this vein also empty the veins seen in the dorsal wall of the heart. Pick out any clots that may be found. Slit the anterior wall of the auricle, being careful not to cross the groove between the auricle and ventricle, and note the muscular columns within the appendage of the auricle.

3. Cut away the whole of the appendage of the right auricle. Remember that the pulmonary veins from the right lung run very close to the right auricle, and be careful not to cut into them. If necessary, pin down the flap of the left auricle, so that water may not enter the left half of the heart in the next

experiment. Hold the heart in the left hand, with the ventral surface in the palm, and the tips of the fingers against the right ventricle. Hold the heart under a faucet, or pour from a pitcher, and let the water run first gently, then strongly, through the right auricle into the right ventricle. Watch the **tricuspid valves** as they float up and separate the auricle from the ventricle. Empty the heart and fill it again, and as soon as the valves rise, press with the fingers on the outside of the ventricle. What effect has this pressure? Let the nozzle of the faucet project down between the valves, and again turn on the water. Where does the water escape?

4. Empty the heart and examine the valves. They will be found lying close against the walls of the ventricle. Note the white tendinous cords attached to the valves.

5. Push the finger past these valves to the very bottom of the ventricle; from the outside cut through the wall of the ventricle at this point, and cautiously cut upward in both directions along the border of the ventricle. Raise the outer wall of the ventricle, and study the valves more thoroughly; with the scalpel handle raise them from the walls of the ventricle. How many flaps are there? How are they arranged? The conical elevations of the muscle to which the tendinous cords are attached are the **papillary muscles**. How are the valves held in place? How are they acted on, and how do they act?

6. Find the connection between the right ventricle and the pulmonary artery; pass a probe up into the pulmonary artery. Cut away enough of the wall of the ventricle to show the beginning of the artery. Cut off the pulmonary artery just before it forks to the two lungs; slip over the faucet the end of the artery connected with the heart, and turn on a little water. Watch closely the base of the artery; turn on more water, and look from below at the base of the artery, to see the filling of the pocketlike **semilunar valves**. Note their number, shape, and arrangement. What is the effect of the stream of water upon them, and what is their effect upon the stream of water?

7. Examine the left auricle, and find where the pulmonary veins enter it. Cut away the lobe of the left auricle; examine its inner surface, and find the openings of the pulmonary veins. Hold under a faucet, and note the action of the **mitral valve**, between the left auricle and the left ventricle. Insert the nozzle of the faucet between the valves, and again turn on the water. Where does it escape? Cut off the aorta half an inch from its base, and repeat the last experiment with the water, meanwhile closely watching the semilunar valves of the aorta.

8. Above the pockets of the semilunar valves look for the openings of the **cardiac** (coronary) **arteries**, which supply the walls of the heart. Probe them. How many are there?

9. Pass the handle of the scalpel between the semilunar valves of the aorta into the left ventricle; it passes back of one flap of the mitral valve.

10. Cut open the left ventricle. Note the strong muscular columns, the strong papillary muscles; the mitral valve, though ending in two main flaps below, is continuous at the top. The valves between the auricles and ventricles are sometimes called the **auriculo-ventricular** valves. This may be shortened to "**aur-vent**" valves, and will be easily remembered, as the parts of the word indicate the two cavities between which the valves lie. Compare the walls of the right with those of the left ventricle. Why this difference? Note the partition between the ventricles. Is there any direct communication between the right and left halves of the heart?

11. Slit open the aorta between two of the semilunar valves, and study the valves more closely. In the middle of the free border of each valve note the little thickened point, the **corpus arantii**. When the valves close, these three little points fill up a small, three-cornered opening that would otherwise be left between the valves. These valves are sometimes called the **ventriculo-arterial**, or, for short, the "**vent-art**" valves, as they lie between the ventricles and the arteries. Again examine the cardiac arteries.

12. In another heart, carefully cut around the base of the pulmonary artery, tie its outer end tightly over the end of a glass tube or spool, and show the action of the semilunar valves, by blowing suddenly and forcibly into the tube. To keep the glass tube from slipping out, slip an inch of thick rubber tubing on the end of the glass tube, so that the rubber tube is even with the end of the glass tube. The valves work better when moist and flexible; therefore keep the preparation standing in a jar of water until it is to be used. Slit open the artery, and study the valves.

13. Longitudinal and cross sections of a frozen heart are instructive.

The Distribution of the Arteries and Veins in the Cat or Rabbit (injected). — Directions for injecting are given in suggestions "To the Teacher." 1. The main artery, the **aorta**, is a thick-walled tube, springing forward from the center of the base of the heart. It soon arches over to the left, and runs along the middle of the dorsal wall of the chest cavity.

2. At the bend, or **arch**, the aorta gives off two branches (three in man). The first of these soon subdivides, giving off a branch to the right fore limb, the **right subclavian** artery; two branches running along the side of the windpipe are the **right** and **left carotid** arteries. The second branch of the aorta runs to the left fore limb, and is the **left subclavian** artery.

3. During its course through the thorax the aorta is called the **thoracic aorta**. Trace it to the point where it runs through the diaphragm. It then becomes the **abdominal aorta**. Turn the stomach and intestine over to the right, and observe the abdominal aorta running along the dorsal wall of the abdomen. Just posterior to the diaphragm, a branch is given off which subdivides, and gives branches to the stomach, liver, and spleen. Farther back a large branch is given off to the small intestine. Follow it as it branches into the mesentery. This is the **anterior mesenteric artery**. Find the branches of the aorta that lead to the kidneys, the **renal arteries**. Some other branches may

be seen, and finally the aorta divides into two large branches, the **common iliacs**, supplying the two hind limbs.

4. Turn the stomach and intestines to the left, and observe the two veins running forward from the two hind limbs. These are the two **external iliac veins**. By their union they form the **postcaval vein.**

5. Observe the veins from the kidneys, the **renal veins**.

6. Trace the postcaval vein to the liver. Observe the vein that gathers the blood from the intestine, the **mesenteric vein**. This vein is joined by a vein from the stomach, the **gastric vein**, one from the spleen, the **splenic**, and one from the pancreas, the **pancreatic**; together these form the **portal vein**, which empties into the liver. Unlike other veins, the portal vein subdivides, distributing the blood into the liver. The blood thus distributed through the liver is re-collected, and by the **hepatic veins** joins the postcaval vein, close to the diaphragm, and almost wholly concealed by the liver.

7. The postcaval vein passes by the liver, through the diaphragm, and on to the right auricle.

8. On removing the skin of the neck, there should be found on each side the large **jugular vein**. Each of these is formed by the union of the internal and external jugular veins.

9. Just before each jugular vein enters the chest cavity it is joined by a vein coming from the corresponding fore limb, the **right** and **left subclavian veins**. The union on each side forms the **innominate vein**. The two innominate veins, uniting, make the **precaval vein**, which enters the right auricle. In the rabbit there are two precaval veins.

THE VALVES IN THE VEINS.

Dissect back the skin from the throat of the rabbit, cat, or dog, till the jugular veins are well exposed. Let the head of the animal hang over the edge of the table; note that as the blood presses back toward the head it causes marked bulging at certain points; with the handle of the forceps slightly stroke

the vein toward the head, watching the bulgings. Dissect out the jugular vein from the head to the shoulder; insert the nozzle of a syringe, first into one end and then into the other, and show the effect of forcing currents in each direction. Cut the vein open along one side, pin inside out to a piece of a shingle, and examine the thin, pocketlike valves. Test the elasticity of the vein. Note the smoothness of its inner coat. Remove a piece of an artery and experiment in the same way with it.

THE KIDNEY.

The structure of the rabbit's kidney may be made out by the following directions, but the sheep's kidney, being larger and essentially similar, may be conveniently used. If the sheep kidney be used, its dissection may be made later.

1. Observe the depression in the inner border of the kidney, the **hilum**.

2. From the hilum trace a slender white tube, the **ureter**, back to the bladder. Find also the renal artery and vein, branching as they enter the kidney through the hilum.

3. With a sharp knife split the kidney like a bean, beginning at the outer border, stopping the cut when a white membrane is reached near the hilum. With forceps pry about to explore the cavity between this white membrane and the body of the kidney. Note the branches of this cavity into the kidney. Note also the extension of the white membrane into these cavities. Make out that the blood tubes extend through these white branches to the outer parts of the kidney. Count these branches.

4. In the center of the white membrane find the opening of the ureter, by which the urine is conveyed to the bladder. Pass a probe through this opening into the ureter.

5. Note the difference in color of the outer and inner parts of the kidney. At the line of change of color find where the blood tubes first branch into the real kidney substance. Examine carefully the cut surface of the kidney to see its markings.

6. **Make a drawing** of one half of the kidney as seen from the inside, showing all the above-named points.

7. Cut across the middle of the kidney at right angles to its length, and make a drawing of this cross section. The projection of the kidney substance into the cavity opposite the ureter is the **urinary pyramid**, and from its apex, from many fine holes, issues the urine which the kidney has secreted from the blood.

DISSECTION OF THE HEAD OF A RABBIT.

1. Remove the skin from the head. Observe the cartilages of the ears and cut them off close to the head.

2. Below and back of the ear is an irregular pinkish mass, the **parotid salivary gland.** The duct which conveys the saliva runs forward over the cheek and opens on the inside of it. The duct is usually hard to see, as it is thin-walled, slender, and of about the same color as the sheaths of the muscles on which it lies. It may easily be mistaken for a nerve, several of which should now be in sight. This duct is much more readily traced in a dog. With sharp, fine-pointed scissors cut into the edge of the duct, insert a black bristle, and push toward the front.

3. Just back of the angle of the lower jaw find a roundish body, the **submaxillary** salivary gland. Its duct runs forward inside the lower jaw and opens under the front part of the tongue. It is rather difficult to trace in the rabbit, but is much easier in the dog.

4. The **infraorbital gland** is just below the front of the eye and its duct opens near that of the parotid gland.

5. The **sublingual gland** is a small, slender gland close to the inside of the lower jaw in front of the base of the tongue, and its duct opens near that of the submaxillary.

6. Observe the muscle that covers the outside of the back part of each lower jaw. This is the **masseter muscle.** Place the fingers on the angles of your own jaw and note the action of the masseter muscles in shutting the teeth firmly together. In the rabbit note the attachment of the masseter muscle to the

under edge of the cheek bone. Trim the muscle entirely away, noting carefully all its connections.

7. The **temporal muscle** is attached to the thin wing, or process, of the jaw in front of the hinge, and passes up inside of the arch of the cheek bone and spreads over the temple. The shortening of the masseter and temporal muscles is what shuts the jaws together. Remove this muscle, observing closely all its relations. Place the tips of the fingers on your temples and shut the teeth firmly together; the hardening of the temporal muscle is felt.

8. After removing the submaxillary glands a muscle may be found on each side attached to the inside of each half-jaw near their union in front. These are the **digastric muscles**; prove that when they shorten they depress the lower jaw. Trace these muscles to their connections at both ends. Review these points till you see clearly how the jaw is opened and shut.

9. Cut away the soft membrane on the side of the mouth. Note its inner surface. Split the two halves of the lower jaw apart in front by a strong knife used from below. Entirely remove one half-jaw, noting a muscle attached to the inner surface of the back part of the jaw. Look at its inner side for the hole where the nerve and blood tubes entered it. Do you find a hole on the outside of the jaw?

10. Examine the tongue; how much of the space does it fill when the mouth is closed? What is its shape? The projections on its surface are called the **papillæ**.

11. Examine the roof of the mouth. Press against it to find whether or not there is bone back of the soft membrane. This is the **hard palate**; note any markings or peculiarities of appearance. Follow it back till you reach the **soft palate**, which has no bony wall just beyond it. Follow the soft palate back, cutting away as much as is necessary of the lateral wall, making the opening cut along the level where the teeth meet.

12. Back of the soft palate is the cavity called the **pharynx**; it is a continuation of the mouth. Trace forward the passage

from the pharynx, over the soft palate, into the **nasal passages** above the hard palate. Trace the pharynx downward and backward to two passageways; the farther one is the **gullet**, or food tube, leading to the stomach; the nearer opening is the **glottis**, or opening to the windpipe, leading to the lungs. Between the glottis and the base of the tongue find the **epiglottis**, a spoon-shaped cartilage, which most of the time stands up close to the base of the tongue; but when food passes it turns down and back and covers the glottis, so that food does not enter the air tube. Study these parts and their movements till their action is clear to you.

13. Split the soft palate and turn the parts aside to find on the sides of the pharynx the small openings of the Eustachian tubes, that lead outward on each side to the cavity of the middle ear.

CHAPTER XIV.

MAMMALIA (*Concluded*).

The Brain and Spinal Cord of the Rabbit. — It will be found helpful to have at hand a well-mounted skeleton of a cat or rabbit. Note carefully (*a*) the cavity of the cranium, (*b*) the cavity in the spinal column, and (*c*) the sides of each neural ring where the bone is to be cut by the bone forceps, as indicated in Figure 1.

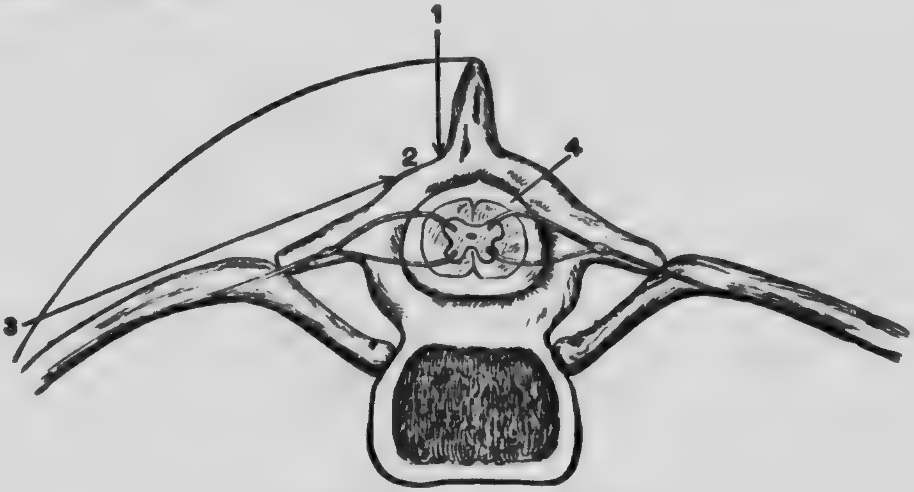


FIG. 1. DIAGRAM FOR DISSECTING SPINAL CORD.

1. Cut along 1 —— 2 with cartilage knife. 2. Cut along 3 —— 2 with cartilage knife. 3. Cut along 4 with bone forceps.

It is best to remove the skin completely before beginning the work, as the fur is likely to be troublesome.

Cut away the muscles from the back of the neck and along the sides of the backbone. This can be done rapidly by making long, deep cuts with the cartilage knife along the sides of the backbone, in the planes indicated in the accompanying figure.

Between the skull and the first vertebra is a space covered by a thin membrane, through which the **spinal cord** may be seen. Carefully cut through this membrane, and insert the point of one blade of a pair of bone forceps at one side of the spinal cord. Cut through this side of the arch of the vertebra; repeat this on the other side, and so on, through the whole length of the spinal column, removing the dorsal parts of the vertebræ, held together in one strip by the connective tissue. The bony cavity in which the spinal cord lies is the **neural cavity.**

The work may be more easily done if the rabbit is supported on the edge of a short piece of "two by four" scantling nailed to a baseboard eight inches wide and a foot and a half long.

Now look for the **spinal nerves**, which leave the spinal cord in pairs, right and left, between the successive vertebræ. It will probably be necessary to cut away considerably more bone to expose the nerves. The whole of this work requires the utmost care and patience, and involves a good deal of hard labor.

Note carefully the variations in the diameter of the spinal cord in its course. The anterior swelling is called the **cervical enlargement,** and the posterior is the **lumbar enlargement.**

When the spinal nerves have all been laid bare, count and compare them in reference to: (1) size; (2) intervals between successive pairs; (3) angles at which they leave the spinal cord.

Carefully cut away the bone around some of the nerves in the region of the shoulder, and find the two roots by which each nerve is connected with the cord, one nearer the back, the **dorsal root,** and one nearer the ventral surface of the body, the **ventral root.** Trace these two roots, and note that they unite and form a spinal nerve.

On the dorsal root, just before it joins the ventral, is a small swelling, the **ganglion** of the dorsal root.

In the region of the shoulder carefully trace several of the nerves as they unite to form the **brachial plexus,** from which nerves supply the fore limb.

In the region of the hips trace several of the spinal nerves

to their union in the large **sciatic nerve**, which runs down the thigh.

Turn now to the head, and cut into the bone between the eyes. Cautiously working backward, the whole of the brain may be unroofed. Great care must be exercised, for here we have one of the softest of the tissues of the body lying very closely beneath one of the hardest. It is possible to do this work with a strong knife, but the bone forceps save a vast amount of extra work. The bone must be broken away bit by bit.

Compare the color of the brain with that of the spinal cord.

The tough membrane covering the brain is the **dura mater**.

The fore part of the brain is the **cerebrum**. Note the groove separating it into the right and left **hemispheres**. Observe the ridges, or **convolutions**, of its surface. The prolongations of the brain between the eyes are the **olfactory lobes**.

Back of the cerebrum is the **cerebellum**. Look at the human skull to see whether there is a bony partition corresponding to that which separates the cerebrum from the cerebellum in the rabbit.

The widening part of the spinal cord within the skull is the **spinal bulb**.

Make a drawing of the brain and spinal cord, showing as many as possible of the points above noted. If desired, the brain and cord, with a short part of each nerve, may be removed from the body and laid on a cushion of cotton in weak alcohol.

Directions for preparing the Brain of a Cat or Rabbit. — Directions have been given above for uncovering the brain. To remove the brain, it will be necessary to cut through the tough **dura mater** that covers it.

Removing this, there will be found an inner covering, the **pia mater**, a membrane richly supplied with blood tubes, from which the brain gets its nourishment. After the dura mater has been removed, the anterior end of the brain may be gently lifted

with the handle of the scalpel and the under surface studied, following the directions in finding the cranial nerves.

The brain may be studied while it is fresh, but it is more easily handled after it has been hardened. Lay the brain in weak alcohol, about twenty-five per cent. It should rest on a layer of cotton, otherwise it may be very much flattened by its own weight, and get a good deal out of shape. Later transfer it to fifty per cent alcohol, and then to seventy-five per cent; or use a solution of alcohol and formalin as follows: ninety-five per cent alcohol, sixty parts; two per cent formalin, forty parts. The liquid need not be changed if used in sufficient volume. When it is well hardened, it may be sliced with a sharp scalpel as directed.

The Brain of the Rabbit (*Alcoholic Specimen*). — The brain of a cat or dog is better, being larger. Take a brain well hardened, and review the parts as named above. It is very desirable to have a specimen in which the arteries have been injected.

1. Press down the cerebellum, to see the deep groove between it and the cerebrum. The thin membrane covering the brain and dipping into the grooves is the **pia mater**.

2. Press down the spinal bulb and tear away the pia mater where it passes from the cerebellum to the spinal bulb. Note, between the bulb and the cerebellum, a space covered by a thin membrane. Cut into this membrane; the cavity is the **fourth ventricle** of the brain. Observe the two ridges bounding the sides of the fourth ventricle. At the point of their divergence, observe the opening of the **central canal** of the spinal cord.

3. Gently separate the cerebral hemispheres, and note the transverse band of white fibers connecting them.

4. Examine the under surface of the brain, and find the roots of the cranial nerves.

The Cranial Nerves. — 1. The **olfactory lobes** (probably cut or broken off) extend forward from the fore part of the cerebral hemispheres.

2. Note that the **optic nerves** join each other before reaching

the brain. Only the first and second pairs of cranial nerves directly enter the cerebrum.

3. Back of the optic nerves, near the middle line, is the **third pair** of nerves.

4. The **fourth pair** extend up on each side into the groove between the cerebrum and the cerebellum.

5. Back of these is the larger **fifth pair**. This pair supplies part of the face, and sends branches to the teeth. It is the nerve affected in neuralgia of the face.

6. Back of and inside of the fifth pair is the **sixth pair**.

7. The nerves of the **seventh pair** are larger, and are farther back and outward. These are the **facial nerves**, and control the muscles of the face and the facial expression.

8. Close to the seventh are the **eighth**, or **auditory nerves**.

9. The **ninth, tenth,** and **eleventh** arise close together, farther back and well up on the sides of the **spinal bulb**.

10. The ninth supplies the back of tongue and the pharynx, and is called the **glosso-pharyngeal nerve**.

11. The tenth pair pass down out of the brain cavity, give off branches to the pharynx and larynx, and are distributed to the heart, lungs, and stomach. These are the **vagus nerves**.

12. The last pair of cranial nerves, the **twelfth**, arise near the middle line of the spinal bulb. This pair supply the muscles of the tongue, and are called the **hypoglossal nerves**.

Draw the brain as seen from below, showing all these nerves.

Separate the cerebral hemispheres, and with a sharp knife split the brain lengthwise in the middle line. Make a drawing of the inner face of one half. Note the branched appearance, the **arbor vitæ**, of the cerebellum. Trace the cavities of the brain.

THE LEGS OF THE RABBIT.

Most of the following structures may be made out from a shin bone of a sheep, readily obtained from the butcher.

1. After removing the skin from the legs, observe the **muscles**,

covered by a thin, glistening membrane, the **muscle sheath**. Study the shapes of the muscles.

2. In the hind limb of the rabbit observe the heel cord, or Achilles tendon, passing upward from the heel along the back of the leg. The tendon is the termination of the calf muscle, which lies on the back of the shin bone. Trace this muscle toward the body, and note that it passes between two large, flat muscles, one on the inner, the other on the outer, back part of the thigh. Separate these two flat muscles, using mainly the handle of the scalpel. Remove any fat that may be in the way. Deeply embedded between these muscles is a white cord, the **sciatic nerve**. Trace this nerve toward the body, cutting away any muscles or soft tissue covering it. How far can you trace it? Now follow the nerve outward. Is it of the same size throughout? What are its relations to the muscles?

3. Study carefully the calf muscle, its shape, color, covering, ends, etc. The end by which its tendon is attached to the heel bone is the **insertion**; the other, less movable end is the **origin**. From what bone does it arise, and by how many tendons? Cut across the muscle at its thickest part, the belly of the muscle, and study its structure. Note that the tendons at the ends of the muscle are continuous with the muscle sheath and with the partitions running through the muscle. Pull the tendon toward the body; this straightens, or extends, the foot; the calf muscle is therefore called an **extensor** muscle. With the handle of the scalpel loosen the muscle on the front of the shin bone; prove that its action is to bend, or flex, the foot. It is a **flexor**. Find its origin and insertion.

4. By further dissection find how the different movements of the toes are effected.

5. Cut into the knee joint. Observe the liquid, the **synovia**, which oils the joint. Rub a drop of it between the thumb and finger.

6. Observe the glistening bands which hold the ends of the bones together. These are the **ligaments**. Carefully study their arrangement and uses.

7. Note the thin layer of **cartilage** over the ends of the bones. Feel of it. Cut it. What are its properties, and what its uses?

8. With the forceps strip off a little of the muscle sheath from one of the muscles and note the color of the latter. Cut one of the muscles across in its middle and examine the cross section. Each fiber has its own thin sheath, and the small bundles of fibers have separate sheaths, which make the white markings seen in chipped dried beef.

9. Tear off a few fine fibers of the muscle, mount on a slide in water or glycerine, cover with a cover slip, and examine first with a low and then with a high power. The fine cross-markings of the fibers give to this kind of muscle the name of **striped, or striated, muscle.**

10. The covering of the bones is the **periosteum.** Thoroughly clean one of the long bones and make a drawing of it. Saw it in two lengthwise and make a drawing of the surface thus exposed. Put a bone into weak acid, and after a day or two compare it with another that has been burned.

THE MUSCLES OF THE EYEBALL.

With bone forceps, or a strong knife, cut away the bone at the outer angle of the eye socket of the rabbit (almost any mammal will serve for this, but the bone is so thick in the calf or sheep that it will be difficult work without the aid of a good pair of bone forceps).

1. With scissors trim away the white membrane around the front of the white of the eye; this was continuous with the lining of the eyelid, and is the **conjunctiva.**

2. Find a muscle running along the roof of the eye socket, which passes over a loop of tendon, near the edge of the orbit, and turns outward to its attachment to the top of the eyeball. This is the **superior oblique muscle.**

3. Beneath the eye find a muscle, having its origin in the inner front part of the socket, and passing outward to be

inserted in the lower surface of the eyeball; this is the **inferior oblique muscle.**

4. Four straight muscles, the **superior rectus, inferior rectus, internal rectus,** and **external rectus,** are attached to the top, bottom, and sides of the eyeball; find the origin of these, with that of the superior oblique, at the bottom of the eye socket.

5. Dissect away the fat and other tissue around these muscles, and find the cone shaped muscle attached to the back of the eye. Within this find the cylindrical **optic nerve.**

External Parts of the Eye. — The eye of the rabbit may be used, but that of the ox is better.

1. Observe the clear front part of the eye, the **cornea.** Note its shape. Observe which end was at the inner angle of the eyelids.

2. Around the cornea find a whitish membrane, the **conjunctiva,** which, a short distance back from the cornea, separates from the eyeball to turn forward and line the eyelid.

3. The several muscles of the eyeball, a mass of fat which forms a cushion for the eye, and other tissue, should be trimmed away, leaving the **optic nerve.**

4. Place the eye in its natural position, and make drawings of it, as seen from the front and from one side, naming the parts.

Dissection of the Eye. — Beef eyes are of good size for dissection. Each member of the class should have an eye to dissect. To supply a large class it is best to send to a slaughtering house in the nearest large city. If the eye muscles and other external parts have already been studied, it will not be necessary to remove the muscles and fat around the eye: in fact, they may well be left untouched, as they serve as a cushion to support the eye during dissection. The eye may be conveniently dissected on a small piece of board or shingle; and if it is desirable to turn the eye, it is better to do so by turning the support, as the eye usually sticks to the support and the dissection may be injured by trying to move it.

CAUTION. — After the eye is opened be careful **not to compress**

it. If the eye be held in the hand while trying to cut its tough outer coat, the jellylike contents are easily squeezed out, ruining the dissection. **Let the eye rest on the board all the time,** and after first cutting into the cornea it is not necessary nor advisable to touch it with the fingers. When studying the lens, be very careful to tip it up gently and compare its front and back surfaces before removing it from the eye.

1. Lay the eye on the board, with the cornea uppermost. Hold the eye firmly with the thumb and fingers of one hand; with the thumb and forefinger of the other hand hold the blade of the scalpel half an inch from its tip; with a steady motion push the blade horizontally through the cornea, near its edge.

2. The liquid in the cavity back of the cornea is the **aqueous humor.**

3. Slightly enlarge the cut horizontally; then with the forceps take hold of the upper edge of the cut, and with the scissors cut around the margin of the cornea and remove it.

4. The dark membrane now exposed is the **iris.** Pinch the eye slightly at the sides to make the iris show more distinctly. The hole in its center is the **pupil.** With the forceps raise the edge of the iris around the margin of the pupil to see that it is here unattached to the structures underneath. Observe the color and markings of the iris.

5. From one end of the pupil cut outward to the outer margin of the iris; then cut around its outer margin and remove it. Observe the color and markings of the posterior surface.

6. The body now laid bare is the **crystalline lens.** Touch it.

7. Lay a piece of newspaper *close* to the eye, on which to receive the lens, which sometimes pops out suddenly. With a very sharp blade make a quick, light gash across the surface of the lens to cut through the thin coat which envelops it, the **lens capsule.** Usually the lens may be made to come out by applying gentle pressure to the sides of the eye with the thumb and finger. If not, enlarge the opening thus made, and carefully pry up the

lens with the handle of the forceps, noting closely, in so doing, the difference between the front and back surfaces. Lay the lens on the piece of newspaper, and look through it at the letters. Make a drawing of the lens as seen from the front, and as seen from one side, naming the front and back surfaces.

8. (CAUTION. — In removing the strip of eye coating, as directed below, be extremely careful not to drag the clear, jellylike vitreous humor. The strip must not be unwound, as in peeling an apple, but must be **left in place**. The parts must be lifted gently by the forceps, and the clear, jellylike mass must be cut through horizontally, with the scissors.) With the scissors now cut outward about one half of an inch from the edge of the hole made in front of the eye, merely cutting through the outer wall of the eye. Beginning at the lower end of this last cut, with scissors cut through the coats of the eye, horizontally, all around the eye. With forceps take hold of the upper edge of the coats of the eye, and lift very gently and steadily while cutting horizontally through the jellylike contents of the eye, in the plane of the circular cut just made. Lay the part thus cut off wrong side up on the board. On the inside of the strip removed there may be found radiating black ridges, the **ciliary processes**.

9. Carefully pick away with the forceps, and snip away with the scissors, everything on the surface of the clear mass beneath.

10. The substance filling the remainder of the eye cavity is the **vitreous humor**.

11. Through the vitreous humor the entrance of the optic nerve may be seen with the blood tubes radiating from it. If necessary, carry the dissecting board to a window to let the light enter from above.

12. The tough outer coat of the eye is the **sclerotic coat**.

13. Inside the sclerotic is the dark **choroid coat**.

14. The inner, nearly transparent, pinkish or whitish coat is the **retina**. At this stage of the dissection it has probably become slightly wrinkled, and the white ridges may be seen radiating from **the entrance of the optic nerve.**

Drag out the vitreous humor and note the soft whitish or pinkish retina; observe that it is a continuation of the optic nerve. Tear away the retina, noting its consistency. Note the color and luster of the inner surface of the choroid coat. The dark layer on the inside of the choroid coat is the pigment layer (outer part) of the retina, which adheres to the choroid, and is torn loose from the rest of the retina.

The reflection of light from this surface of the choroid coat causes the color seen in the eyes of some animals. Turn the remaining coats inside out, and tear the choroid coat from the sclerotic. Observe the blood tubes passing from one to the other.

DISSECTION OF THE LARYNX.

The Larynx of the Calf. (As the larynx of the rabbit is so small, it will be better to examine a larger one.) — 1. The front of the larynx is readily distinguished by the projection of cartilage known as the **Adam's apple.**

2. Along the back of the larynx runs a thick, muscular tube, the **gullet**, with a whitish lining, the mucous membrane.

3. Trim away the muscles and other tissues from the front and sides of the larynx. The large cartilage forming the greater part of the front of the larynx is the **thyroid cartilage**.

4. Observe the band of muscles attached to either side of the thyroid cartilage and passing horizontally back around the gullet or esophagus.

Cut away this muscle as completely as possible, and entirely remove the gullet. Note that the whitish or yellowish **mucous membrane** which lines the gullet is continuous with the lining of the larynx. Study now more fully the shape of the thyroid cartilage.

5. Back of the upper part of the thyroid cartilage, covering the upper end of the larynx, is the arched **epiglottis**. Feel of it to learn its consistency. Press it upward and forward, then downward and backward; observe that it now covers the entrance to the larynx; note the position it takes when released.

6. Just back of the upper angle of the thyroid cartilage find a muscle connected with the base of the epiglottis; pull this muscle to determine what effect its shortening produces on the epiglottis.

7. Under the thyroid cartilage in front observe a narrow ring of cartilage not much wider than one of the rings of the trachea. Move this up and down to prove that it is distinct from the thyroid. This is the **cricoid cartilage**.

8. Observe the sheet of muscle passing from the cricoid to the thyroid. Again move the cricoid toward and from the thyroid. What does this muscle do? Cut away this muscle from one side, and see that the cricoid cartilage widens as it passes backward. How are the cricoid and thyroid hinged together?

9. Projecting upward and backward from the top of the larynx are two curved yellowish cartilages, the **arytenoid cartilages**. Move them about to see that they are movable, and that they rest on the upper edge of the back part of the cricoid cartilage.

10. Move the arytenoid cartilages backward and forward, meanwhile watching the inside of the larynx from its lower opening. The projecting ridges, which meet just back of the Adam's apple, are the **vocal cords**. What effect is produced on the vocal cords by the movements of the arytenoid cartilages?

11. Observe the connection of the thyroid cartilage with the cricoid by means of a downward projection of the former. Cut away all of this half of the thyroid cartilage. Notice the slender **hyoid bone** loosely connected with the upper horn of the thyroid.

12. Examine now the muscles which move the arytenoid cartilages.

a. On each side of the posterior surface of the cricoid is a muscle passing upward to be attached to the corresponding arytenoid; this is the **posterior crico-arytenoid muscle**. Dissect it loose from the cricoid at its origin below. By pulling, determine its action on the arytenoid, and through the arytenoid on the vocal cord.

b. Arising from the upper edge of the side of the cricoid cartilage, and passing upward and backward to the arytenoid, is

the **lateral crico-arytenoid muscle**; cut it away at its origin close to the cricoid, and demonstrate its action on the arytenoid cartilage and vocal cord.

c. A broad muscle arising along the whole length of the angle of the thyroid, whose fibers converge to the arytenoid cartilage. This is the **thyro-arytenoid muscle**; cut it across near its origin, dissect it loose, and by pulling it toward its origin prove its action.

d. On the posterior surface of the arytenoids is the small **arytenoid muscle.**

13. Cut between the arytenoid cartilages and remove one of them. Examine the joint between the arytenoid and cricoid. Note the synovia lubricating the joint.

Trim away the muscle from the arytenoid cartilage and study its shape more fully. Fit it again to its place, and recall the motions given by each muscle.

14. Now examine the arytenoid cartilage and the vocal cord of the opposite side; move the arytenoid back and forth, watching the vocal cord.

15. Remove the epiglottis, and cut into it to see its structure.

16. Dissect away the parts of the other side from the inside, reviewing the above points.

THE SKELETON OF THE RABBIT.

Carefully clean the skeleton after dissecting away the muscles. In preparing the skeleton in this way the student will learn many facts as to the relations of the bones to the other tissues, that he would not learn if he began with a well-mounted museum skeleton.

In removing the muscles, observe that the muscles of the limbs lie parallel to the bones; that the bones are largest at the ends, while the muscles are thickest near the middle, thus making the two fit each other better. Note that in the limbs the muscles narrow at one end, or both, into a **tendon**, which, usually at one end, passes over a joint to be attached to a bone

in the next part of the limb. Examine the **ligaments** that hold the adjoining ends of the bones together. Examine the **cartilage** on the end of the bones. Between the ends of the bones of the limbs, note a small quantity of slippery liquid, the **synovia**. In cleaning the bones, notice the nerves and blood tubes passing in and out of the holes along the sides of the bones.

Weigh a rabbit, freshly killed, but from which the blood has not been removed. Thoroughly clean the skeleton, and when it is dry, weigh it. What part of the whole weight of a rabbit is the skeleton?

1. The skeleton consists of two parts, the **axial part**, made up of the skull and spinal column, and the **appendicular part**, consisting of the limbs and the bones supporting them.

2. In the skull, the joints are called **sutures**. The bones surrounding the brain constitute the **cranial** part; those parts in front make up the **facial** part. Note that the face is large, compared to the cranium. How do these two parts compare in the rabbit, dog, horse, frog, ape, and man? Why so much difference? Note the cavities and apertures in the skull: the brain cavity; the opening (foramen magnum) through which the spinal cord passes to join the brain; the cavity, or **orbit**, of the eye, with its holes for the optic nerve; the **nasal apertures** at the front of the snout; the **auditory apertures**, or ear holes. On each side of the foramen is a smooth, rounded elevation; these are the **occipital condyles**. See how they fit the first vertebra; what kind of a joint do they make? Study again the way the lower jaw joins the skull, and consider the motions that this joint permits. Compare it with the corresponding joints in the skulls of a cat, cow, and man.

3. Make a more careful study of the teeth than before, as they are now fully exposed. The front teeth are the **incisors**; what is their shape. How many above? How many below? Are they all alike? How are they arranged? Are they all marked alike? How do the upper and lower incisors meet, —

squarely, edge to edge, or does one pair naturally rest back of the others? If so, which are in front in the resting position? Can the lower jaw be moved forward and back? Do the lower incisors always come up in the same position in relation to the upper incisors? Note the angle at which the incisors are set. Now examine the grinding teeth, or **molars**. How many are there in each half-jaw? What is their shape? Are there ridges on their grinding surfaces? If so, in what direction do they run? How is this related to the chief chewing motion? Are all the molars set at the same angle? Why any difference? At this point, if possible, look again at a live rabbit and watch the process of eating. How are the jaws moved, and how do the motions stand related to all these facts about the teeth?

4. Take a well-cleaned lower jaw of a rabbit. Embed it in sealing wax on a small block of wood, with the inner face of the jaw uppermost. With a grindstone, grind away half of the incisor and the surrounding jawbone. Is there a distinct root? Is the tooth equally hard throughout? The front part is **enamel**. The bulk of the tooth consists of **dentine**, or ivory. Grind away half of the molars and the bone in which they are set. Do any of these teeth continue growing after the rabbit has reached maturity? Is it a serious matter for a rabbit to lose one of its front teeth? Why?

5. Each separate piece of the backbone is a **vertebra**. The vertebræ of the neck are called **cervical vertebræ**. The vertebræ that bear ribs are **thoracic**. Following the thoracic vertebræ are the **lumbar vertebræ**. After these, are several grown together and supporting the bones of the pelvis; they constitute the **sacrum**. Last, the vertebræ of the tail, the **caudal vertebræ**. How many are there of each of these kinds? How many in all? Review the whole spinal column, comparing the different parts.

Take a vertebra from the middle of the thorax and examine it carefully. Its main part is the **body** or **centrum**. On the dorsal side is an arch, the **neural arch**, through which the spinal cord passed. Above the arch is a projection, the **neural spine**, the

row of neural spines forming the ridge of the backbone. Extending outward on each side are the two **transverse processes.** Near the end, on the dorsal surface, are the two smooth **facets,** where the vertebra joined the vertebræ before and behind it; these are the **articulating processes.** Do all the vertebræ have the same number of the processes? Where the same number is present are they alike? What range of motion is allowed between two vertebræ? Is this equal in different parts of the spinal column?

6. Study carefully the first and second vertebræ. The first is the **atlas.** Has it a body? Note how the two hollowed facets on each side of the hole fit the two occipital condyles of the base of the skull. How is the nodding motion of the head accomplished? The second vertebra is the **axis.** Projecting forward from it is a peg which extends into the opening in the atlas; this peg is the **odontoid process.** Observe that when the head turns from side to side it is by turning on this axis.

7. Examine one of the middle ribs. Find that it joins the backbone in two places, by its **head** on the side of the vertebra, and by a little projection called the **tubercle,** with the tip of a transverse process. What range of motion has a rib? Note that at the ventral end the rib is cartilaginous. What is the advantage of this fact? Compare the series of ribs. Examine the breastbone. Is it of one piece? Is there any cartilage in it? What are the uses of the ribs? Is there a **collar bone**?

8. In the fore limb look at the shoulder blade or **scapula.** How does it make up in strength for its thinness? Why should it be flat? Note the shallow cavity by which it articulates with the bone of the upper arm, the **humerus.** This is a **ball-and-socket joint.** Look closely for a slender collar bone, or **clavicle.** In the forearm the longer bone is the **ulna**; the other is the **radius.** Do they rotate on each other as in our forearms? Compare them also with the corresponding bones of a cat. Do they need the same freedom of motion as in a cat, squirrel, ape, or man? The bones of the wrist are the **carpal bones.** The

bones of the palm are the **metacarpal bones**. Beyond them are the finger bones, or **phalanges**. Find how many there are of each of these sets.

9. In the hind limb each half of the **pelvis** consists of the long **hip**, or **innominate bone**. Note the deep socket of the ball-and-socket joint. Fitting into this is the rounded head of the **femur**, or thigh bone. Compare this joint with that of the shoulder. Which has the greater range of motion? Which the greater strength? Study the kneejoint. Note the kneepan, or **patella**, in the tendon running over the kneejoint. The large bone of the leg, or shank, is the **tibia**. Beside it is the **fibula**; is it wholly free from the tibia? If it is found united with the tibia, where and to what extent? Corresponding to the carpus of the wrist, there is a series of short bones in the foot constituting the **tarsus**. Then comes a row of longer bones, the **metatarsal bones**. And after these are the toe bones or the **phalanges**. How many in each of these series and how arranged? Are the bones of the same number as in the fore limbs?

CHAPTER XV.

PROTOZOA.

AMŒBA.

Amœbæ are to be found in standing water, where they live in the slimy coating on the leaves and stems of submerged plants, or on the upper layer of mud or ooze at the bottom. Such water with mud and plants should be collected sometime beforehand and kept undisturbed in the laboratory.

1. Take a drop of water from the bottom or the surface of a leaf, mount on a slide, and cover with a cover slip. Examine with a high power of the microscope, using a one-fifth or a one-sixth inch objective.

2. **General Appearance.** — An amœba looks like a small drop of clear jelly, but after watching it a short time it may be seen to change its form. The body is composed of a substance called **protoplasm**.

3. **Structure.** — The following parts should be identified: —

a. A clear outer margin, the **ectosarc**.

b. A dotted or granular inner portion, the **endosarc**.

c. A denser, spherical body within the endosarc is the **nucleus**.

d. A clear space that from time to time contracts and disappears. This is the **contractile vesicle** or **vacuole**. Are its pulsations regular? Time them.

e. Other vacuoles that do not pulsate but are filled with granules of food materials. These are called **food vacuoles**.

4. **Movements.** — Watching the amœba closely shows that it not only changes its form, but also its position; it not only moves, but moves from place to place. It has not only motion, but locomotion. By closely watching an amœba it may be seen

that at one place there is a bulging out of the ectosarc, sometimes forming a long projection called a **pseudopod**. The granular endosarc then flows into this projection, and by repetition of this process the whole amœba moves forward. Is there any part that can be called the head? Does it move constantly in any one direction? Make sketches at intervals to show the changes in form.

5. **Feeding.** — It may be discovered that occasionally an amœba ingulfs a particle with which it comes in contact. This is its mode of eating, for it has no mouth. Does it show choice in what it thus takes in? Is there any refuse of digestion? If so, where and how does it leave the body?

6. **Feeling.** — Does the amœba ever appear to feel an object against which it presses? Does it avoid obstacles? What evidences as to its having a sense of touch?

7. **Reproduction.** — Can you find an amœba that is dividing into two parts? This is its simple mode of reproducing, and is called **division** or **fission**. If possible, find out how long it takes to complete the division. Make sketches to show the process of division.

PARAMECIUM, THE SLIPPER ANIMALCULE.

Paramecia are often found in water containing decaying animal or vegetable matter. If a white film forms on the surface of such water, look through the sides of the jar, and there may often be discovered tiny white particles moving actively about. Mount a drop of this water, with a little of the scum, and examine with a low power of the microscope, say a two-thirds or one-fourth inch objective. Small oval or elliptical bodies may be seen swimming around at a lively rate. These are paramecia. Find one that is fenced in by surrounding matter, or prepare another mount; a few threads of cotton often serve well as a "corral." With a higher power, one fifth or one sixth, examine a paramecium, whose movements are thus restricted. Note: —

1. **The shape**, oval or elliptical, often decidedly slipper-shaped. It further resembles a slipper in being somewhat flattened.

2. **Structure.** — The clearer, firmer, outer layer is the **ectosarc.** The more jellylike inner part is the **endosarc.** Covering the ectosarc is a thin, transparent layer, the **cuticle.** Extending from the ectosarc through the cuticle are many fine, hairlike projections, the **cilia.** Near the center is a large, ovoid body, the **macronucleus.** Beside it is the much smaller **micronucleus.** These nuclei are hard to see. Place a little dilute acetic acid on the slide close to the cover slip to bring out the two nuclei.

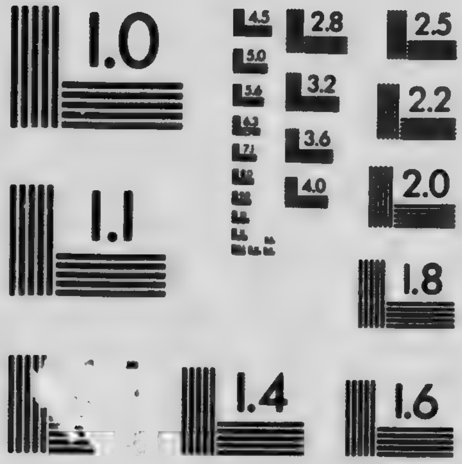
3. **Locomotion.** — The paramecium swims by means of the vibrations of the cilia. Does it swim with the same end always foremost? Does it change its shape? Watch it when trying to pass into a narrow opening. Are the cilia of the same size all over the body? Place a drop of iodine solution on the slide at the edge of the cover slip. The cilia, thus stained, show better.

4. **Feeding.** — Along one of the flattened surfaces find a groove, the **oral groove.** Note the cilia lining this groove. Observe that, near the center of the body, the oral groove becomes a tube dipping into the body. The tube is the **gullet,** and its beginning is the **mouth.** Sift finely powdered carmine or indigo into the water, and watch to see the particles swept into the gullet by the action of the cilia. The masses of particles that accumulate at the end of the gullet become separated from the gullet, and as distinct masses in the body are called **food vacuoles.** Do the food vacuoles remain in the same place? Or do they move about? Do they move in any regular order? Can you find a place where the residue is expelled from the body?

5. **Pulsating Vacuoles.** — About one third of the way from each end, look for a clear space, which contracts and disappears, and then reappears; these are the pulsating vacuoles, or contractile vesicles. How often do they pulsate? Which takes more time, contraction or dilation? Look closely for radiating canals after

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



the disappearance of a vacuole. Do the two vacuoles contract at the same time?

6. **Means of Defense.** — Observe in the ectosarc many small, oval sacs, with their ends toward the surface. These are the **thread cells.** They contain a thread, which can be shot out, serving as a means of defense.

7. **Reproduction.** — Do you find a paramecium that is becoming constricted in the middle like a dumb-bell or hourglass? Paramecium divides into two by narrowing in the middle, preceding which is a division of the nuclei. If such a specimen can be found, watch the process to completion, if possible. Draw and describe all the stages of division, or **fission.**

VORTICELLA, THE BELL ANIMALCULE.

Vorticellæ are often found on the stems and leaves of water plants, or on stems and leaves that have fallen into the water. Mount slender stems from water and examine with a low power. If you find a bell-shaped form attached by a slender, flexible stalk, and especially if the stalk is suddenly thrown into a coil, jerking the bell close to the stem to which it is attached, you may be sure you have vorticella or a near relative. Some of these forms occur in colonies, all growing from one main stalk. Some have the power of coiling the stalk, while in others the stalk is not contractile. Some of the colonies can be seen by the naked eye, appearing like tiny spots of mold. If such a colony is found, the part of the stem or leaf to which it is attached should be carefully cut out and mounted on a slide. With a higher power the details of form and structure may be studied.

1. **Form and Structure.** — The body is bell-shaped, with a long, slender, flexible stalk in place of a handle. The outer layer is a thin cuticle, next is the **ectosarc**, and the inner is the **endosarc.** The extension which nearly fills the mouth of the bell is the **disk.** The border of the bell is the **peristome.** On one side find a groove between the disk and the peristome. This

is the **oral groove**. Observe the cilia along the margins of the disk and the peristome. The extension of this groove into the body forms the **gullet**. Vorticella has a long, curved macronucleus and a small, spherical micronucleus, but these are not easily seen. Add a little dilute acetic acid.

2. **Movements.** — Observe carefully the stalk during and after the coiling. The stalk does not contain any of the endosarc, but only the ectosarc and cuticle. Note also the changes in the shape of the body and the rearrangement of the parts. In what order are the parts folded in during the act of closing, and in what order are they expanded when the vorticella extends again? Tap on the slide while watching to see these changes. Make sketches showing the fully expanded and the closed forms. Why does the vorticella thus draw itself close to its support?

3. **Feeding and Digestion.** — Watch the vibrations of the cilia. Can you see that food particles are swept into the oral groove and down to the blind end of the gullet? Add powdered carmine or indigo to the water. Can you see food balls at various points in the endosarc? Are they stationary, or do they move? If they move, do they go in any regular order? Look closely for the expulsion of residue into one side of the gullet, and so out by the return current. Does a vorticella move toward food? Could it do so? Does it need to do so? Does vorticella show choice in the particles that it takes as food?

4. **Excretion.** — Find the **pulsating vacuole**. Time its contractions.

5. **Senses.** — What senses does the vorticella appear to possess?

6. **Reproduction.** — Look for two vorticellæ on one stem. You may find one in the early stages of division. When one of these becomes separated, learn how it swims away. Study vorticellæ a long time to find out about the mode of development, making sketches of what you observe.

Topics for Reports. — Chalk. Barbadoes Earth. Malaria. Infusorial Earth.

CHAPTER XVI.

PORIFERA.

SPONGES.

Each pupil should have a small specimen of a commercial sponge, showing large holes at the top, but not with large holes running straight through.

The teacher will need several specimens of larger sponges; one of the simple calcareous sponges, in alcohol; a piece of commercial sponge in alcohol, showing the sponge flesh still in place; a siliceous sponge; and slides showing sponge spicules.

The pupil should make out the following points from his specimen of common sponge: —

1. Its elasticity; test first the specimen dry, and again after wetting it. Compare the elasticity of different kinds of sponges.

2. The fibrous structure; with forceps tear off a bit of the sponge and examine with a lens. Then examine under the microscope.

3. The sponge was attached by its basal surface to rock. Find where it has been trimmed away with shears; perhaps if this has not been thoroughly done, some bits of rock may be found clinging to the base.

4. Examine now the different channels by which the sponge is perforated.

a. Large, craterlike tubes, opening at the top of the sponge. Looking into these, it may be seen that they give off branches. If you can see right through the sponge by looking into these openings, you may know that too much of the base has been cut away, and your specimen is not a good one. With a razor or

sharp knife, cut the sponge in two down one of these large tubes, and examine from the inside.

b. Trace the branches of the large tubes by gently pushing into them a probe (a wire with a little knob on one end). These lead, usually, to holes seen on the outside.

c. Grooves on the surface of the sponge, some shallow, others already becoming inclosed by the union of the tufts of fibers outside of them; in this way is formed another set of tubes (*d*).

d. Tubes running parallel to the surface of the sponge, whose cut-off ends may be seen near the margins of the split sponge. Hold the half sponge up to the light to see the radiating fibers and the concentric series of holes indicating the mode of growth of the sponge.

e. Minute branches of the above tubes penetrating the sponge in all directions.

It must be borne in mind that the sponges we buy are only the skeletons of sponges. In the living sponge the skeleton is entirely embedded in soft living matter, and the skeleton cannot be seen on the exterior; in fact, its fibers are not very evident in a section of a fresh sponge. The outside of the sponges whose skeletons we buy, when alive resembles, in color and general appearance, the back of a kid glove, varying from dark reddish brown to almost black. The consistency of the living sponge is about the same as that of beef liver. If one of these live sponges be watched, a current of water is found to come out of the larger holes at the top, and currents pass in through the numerous smaller holes on the exterior.

If the sponge be handled, many of the smaller holes close and entirely disappear.

In order to understand a little more clearly the structure of the common sponge, and to see how the currents of water are maintained, an examination of a simple sponge will be useful. Our simplest sponges have no elastic skeleton composed of horny fibers like those of the commercial sponge, but have little needle-shaped and three-pronged spicules of limy matter.

One form common on the northern Atlantic coast is a simple or branched white tube, an inch or so in height, and sometimes as thick as a pigeon's quill. These are in clusters, attached by one end and open at the other. Embedded in the wall of each tube are the spicules above mentioned, projecting both on the outside and on the inside. The inside of the tube is lined with cells bearing cilia which, by their vibration, drive the contained water out of the mouth of the tube; to replace which, water enters through many holes which pierce the wall of the tube. In sponges a little more complicated, the cilia, instead of lining the main tube, are limited to small pouches, or lateral branches of the main tube, extending into the body wall and communicating with the exterior through small pores. In others the cilia are found only in certain enlarged portions of these radiating tubes. This represents the condition in the commercial sponges; certain cavities are lined with cilia and are connected on the one hand with the smaller tubes entering the whole surface of the sponge, and on the other with the large tubes opening at the top. These cilia cause the currents above mentioned. Thus the sponge gets both food and oxygen.

Sponges (including, besides those already mentioned, siliceous sponges, whose spicules are flinty) constitute the branch **Porifera.**

Read *Commercial and Other Sponges*, Hyatt.

Topics for Reports. — Sponge Fisheries. Experiences of Divers. Sources of our Sponges. Fresh-water Sponges.

CHAPTER XVII.

CŒLENTERATA.

THE FRESH-WATER HYDRA.

THE fresh-water hydra has a cylindrical **body,** varying in diameter from the size of a fine needle to that of a common pin, and from one fourth to one half an inch in length. It is found in fresh-water ponds and streams, usually attached by one end to submerged stems, leaves, etc., frequently on the under surface of a leaf. Surrounding the free end of the hydra is a circle of threadlike appendages, the **tentacles,** which often are longer than the body itself.

Two species of hydras are found: one green, the other brown or flesh colored, often whitish. Put the leaves and stems to which the hydras are attached into shallow dishes, such as fruit dishes, and keep them in a light but shaded place; watch their behavior when thus kept undisturbed. Cut off a bit of leaf bearing a hydra, and transfer it to a deep watch crystal half full of water. Without the aid of any lens watch the hydra for several minutes. When it is expanded, gently touch it with the tip of a pencil or other blunt object.

Examine a hydra with a hand lens; are all parts colored alike? Place the watch crystal on the stage of a microscope and examine with a one-inch objective. The following points of structure should now be made out: —

1. That the body is a **hollow tube** closed at one end and open at the other. This opening, within the circle of the tentacles, is the **mouth.**

2. That the tentacles are also hollow tubes, closed at their outer ends, but at the inner communicating freely with the body cavity.

3. That the body wall consists of two layers, which are continuous with the corresponding layers of the tentacles. How do these layers differ from each other?

The body is, then, a double-walled sac, and the tentacles are simply extensions of this sac. Watch the movements of the different parts of the body. Can hydras move from place to place? If so, how is this accomplished? Look in the body cavity for foreign matter which has been taken in through the mouth as food. Look also for minute particles obtained by the digestion of such food matter. These particles may often be seen in motion, caused by contractions of the body walls, or by the action of flagella lining the body cavity. Look for knoblike extensions of the side of the body. **Buds** are formed as outgrowths of the body walls with a cavity continuous with the body cavity. Place in a dish by itself with some aquatic plants, a hydra bearing buds, and watch from day to day the development of the bud into the form of the parent. Observe the free circulation of food material from the parent to the bud. Watch the formation of tentacles. Look also for a thinning away of the free end of the bud.

What is the greatest number of buds found on any one specimen? Are buds borne on buds? By means of a pipette transfer a hydra in a large drop of water to a slide. Cut two strips of paper a quarter of an inch long and one sixteenth of an inch wide, and lay one on each side of the drop of water. Carefully place the cover slip on the water, with its edges resting on the papers so as not to crush the specimen.

Examine now with a quarter or one-fifth inch objective. Observe the cells of which the body walls are composed. Note the knotty appearance of the tentacles. In these projections of the tentacles and in the walls of the body are certain distinct oval cells, the **thread cells**. Place a drop of acetic acid on the slide at one edge of the cover slip, and touch the opposite edge of the cover slip with a piece of blotting paper, meanwhile watching the specimen closely. Examine carefully to see the thread

cells which have been discharged as a result of the irritating acid. Small animals coming in contact with the tentacles are paralyzed by means of these thread cells which are suddenly shot out; the tentacles then carry the victim to the mouth, and it is swallowed.

Note the simplicity of the structure of hydra — the absence of any distinct nervous system, and all special organs of circulation and respiration. On the side of a hydra, near the base, may sometimes be seen a conical elevation, the **ovary**, in which the eggs are produced. Also on the side of the body, but near the tentacles, may sometimes be found several elevations, the **spermaries**, in which the sperm cells are produced.

THE SEA ANEMONE.

Look for sea anemones attached to rocks. The beginner in this sort of collecting and observation is usually not prepared for what he sees; he does not usually realize that the name "sea anemone" is exceedingly appropriate, and he is not likely to look for brilliant forms, like sunflowers, asters, and chrysanthemums. Watch them both in their expanded and in their contracted condition. When they are expanded gently touch them. Are they firmly or loosely attached? Do they ever move about? Have they any means of getting food?

In its general form the sea anemone resembles a hydra, having a cylindrical, hollow body attached by one end to some foreign object, and at the free end a mouth surrounded by tentacles. In its internal structure, however, the sea anemone presents some new features. The mouth, instead of opening directly into the body cavity, as in the hydra, opens into an esophagus which hangs like a bag suspended in this cavity; the esophagus has no bottom, but at its lower end communicates freely with the body cavity.

The body wall and esophagus may be represented by a glove finger with its tip cut off and the open end turned back part way into the larger part of the finger.

The cavity of the body is divided into a series of radial compartments by fleshy vertical partitions, the **mesenteries**, which extend inward from the body wall, some reaching the esophagus and being attached to it, others not extending so far inward as the esophagus. Each tentacle communicates with one of these radial compartments, and is to be regarded as a mere extension of part of the body cavity.

Alcoholic specimens should be sliced transversely and longitudinally. In a transverse section of the lower part of the body there will be seen the body wall with a series of partitions extending inward and ending in a free edge. The section across the upper part of the body shows an outer circle, the body wall, an inner circle, the stomach wall, and, connecting the two, the radially arranged partitions, or mesenteries. Like the hydroids, the sea anemone is well provided with thread cells.

Food is taken into the mouth, digested in the stomach, then passed, mixed with sea water, into the body cavity, through which it is made to circulate by the contractions of the body walls. The indigestible portions of the food are expelled from the stomach through the mouth.

STONY CORALS.

(*Coral Proper.*)

In a piece of stony coral, or compound skeleton of a colony of coral polyps (*Galaxea* is a good form to study), make out the following points: —

1. The nature of the material itself; test by putting a very small piece into weak acid, or by touching the specimen with a drop of acid.

2. The **cup**, or **theca**, formed by an individual polyp, often traceable as a long tube. Observe: —

a. The outer wall of the cup.

b. The partitions, or **septa**, extending inward from the wall of the cup.

3. **Between** the cups, the porous limy secretion, which was

secreted by the common body substance, or cenosarc, connecting the individual polyps.

Imagine the sea anemone depositing limy matter in the base of its body wall, forming a cup; fleshy radial ridges rising from the floor and wall of the cup between the mesenteries, and a similar deposit in these ridges; thus it will be seen how the cup is formed by the individual polyp. By the continued growth of the polyp, and the continuation of the limy deposit, the cup becomes an elongated tube. By budding are formed the branches of these tubes, increasing in size and in the number of partitions as they grow.

4. Between the cups, a porous secretion of the same material as that in the cups. This is deposited in the common fleshy base, filling up, in some forms, the spaces between the cups; and when one polyp dies, its cup is covered over and buried out of sight by this secretion of the common base.

5. Make a drawing of a mass of stony coral, showing the general arrangement of the cups, their mode of branching, and the common secretion between them.

6. Draw a cup as seen from its free end. Make also a drawing of a cross section of the same cup toward the smaller end.

In the stony corals the mesenteries are always in pairs, and the fleshy ridges, in which are secreted the septa, arise between them.

The tentacles are generally in multiples of six, and are not fringed. It is of this kind of coral that the reefs are formed.

SEA FEATHER, OR SEA FAN.

In a sea feather, *e.g.*, *Muricea*, note: —

1. An outer barklike layer; with the thumb nail scrape off a little of this layer and pulverize it between the thumb and finger; mix this powder with water and examine under a microscope. A better way to see the spicules is to clean them thoroughly by boiling some of the outer layer in caustic potash. In this layer are holes from which the polyps protruded. In this

form, then, the secretion is wholly in the living matter between the polyps, the barklike layer being composed of the dried flesh in which the spicules lie embedded.

Strip off a piece of the barklike layer and note the grooves on its inner surface. By examining the end of this piece it may be seen that these grooves are caused by a series of tubes running lengthwise near the inner surface of this layer. Find the openings of the tubes where they were broken; these tubes connect the polyps of the colony.

2. The central axis of hornlike substance. Test its flexibility and strength. Observe the grooves on its surface, and the relation between them and the tubes above noted. This horny axis is excreted by the walls of these tubes, and is not penetrated by living matter like the outer layer. In the precious red coral the central axis is formed in the same way, but is calcareous instead of horny, and the outer barklike layer has been removed.

3. Note the mode of branching in a sea fan, comparing the margin with the central portion to see how the meshes are formed. Remove some of the outer layer, and compare with the sea feather. In this group (including sea feathers, sea fans, the precious red coral, etc.) each polyp has eight fringed tentacles; also eight mesenteries, which are never in pairs. An alcoholic specimen, with the polyps expanded, should, if possible, be examined.

Topics for Reports. — Coral Islands and their Formation.

CHAPTER XVIII.

ECHINODERMATA.

STUDY OF A LIVE STARFISH.

STUDENTS who can visit the coast may make profitable study of starfishes in their native haunts. At low tide wade along the shore, looking in tide pools, among rocks and seaweeds, under wharves, etc., for starfishes. Are they found in any special situation? Are they more abundant on one kind of surface than another? Do they seem to prefer sheltered places? Has their color any relation to their surroundings? Are they found in strong light, or do they seem to prefer shaded spots? Do they move? If so, at what rate? Do you find them on the vertical walls of rock? Can they climb? Do they adhere to the surface? If so, how strongly? Try to pull one away from a smooth surface on which you find it. Are they extended flat, or more or less curled up? Are the rays evenly spread out? Do they change the position of the rays to any extent? Are they found singly or in groups? Do they seem to live in colonies? Do you find them eating? If so, what do they eat, and how? Has the situation where you find them in numbers any relation to a food supply? Have they any preference as to the temperature of the water? Are they seriously affected by extreme changes in temperature? At how great depth are they found? Have starfishes any natural enemies? Have they any means of defense? As you reach out to take a starfish, does it seem to be aware of your presence? Is it affected by strong light? By your shadow? By additional heat? By sound? Does it in any way appear to shrink away from you as you take hold of it? Has it any means of stinging or irritating your hand?

Put a live starfish in an aquarium filled with sea water and watch it. Does it move about? Does it crawl up the sides?

How strongly can it hold to the surface it is on? Watch the actions of the tube feet through the glass. Will it climb on a slender suppo , such as a cane, or large glass tube? Can you learn about its food and mode of eating? Try to get answers to the questions asked above as to the live starfish at home. Do you find any evidences as to the mode of development and growth of starfishes? Do the adults have any care of the young? Do starfishes do any good? Have they economic importance? Do they do any harm? How can their ravages be checked?

EXTERNAL FEATURES OF THE STARFISH.

For this work there is needed: —

1. A set of dried specimens, one for each student; such a set may be used with successive classes and will last for years if carefully handled and kept in a dry place.

2. Alcoholic specimens for dissection.

3. It is desirable to have a set of prepared slides, showing cross sections of a decalcified ray of a young starfish, and a ground-down section of a calcareous plate, etc.

4. An injected starfish and a number of injected rays.

Dried Specimen.

1. Observe, first, the shape of the body as a whole. The central portion is the **disk**, and its radiating extensions are the arms, or **rays**. Note that the rays are bilaterally symmetrical.

2. The mouth is at the center of a thin membrane in the middle of the **oral surface**; the opposite surface is called **aboral**.

3. Cut into one of the rays. Observe that the body cavity is bounded by a leathery wall, in which are embedded hard plates. Compare a piece of a ray of an alcoholic specimen with the dried one.

4. Test the flexibility of the integument of the alcoholic specimen. By picking with forceps, prove that there is soft matter, both on the outside and on the inside of the hard plates.

To show the real nature of the plates and their relation to the integument, proceed as follows: —

a. Handle a starfish which has been decalcified, *i.e.* has had its calcareous matter removed by very weak (two per cent) nitric acid, chromic or other acid. Observe that the body wall is still present, but lacks the hard parts.

b. Examine a microscopic section of a decalcified ray of a young starfish; in such section it should be more clearly seen that the calcareous plates are wholly within the integument.

c. To show still further the relation between the plates and the integument, prepare a thin section of a calcareous plate, as follows: select some pieces of a starfish (left from previous dissection); boil a few of the larger plates in caustic potash in order to remove all the organic matter; wash, and when thoroughly dry, smooth down one side on a fine file; polish on a perfectly clean oilstone; cement the surface of the plate to a glass slide by means of a drop of Canada balsam which has been boiled on the slide, until, on becoming cold, it is with difficulty indented by the thumb nail. Proceed then to plane off, by means of a file, and when quite thin, scrape carefully with a sharp knife, finally smoothing it on an oilstone. The specimen should be examined from time to time under the microscope, in order to ascertain when the proper degree of thinness has been reached. Dissolve the balsam by means of turpentine, or better, if properly managed, melt the balsam over a lamp, and carefully push the section into a watch crystal containing turpentine; when thoroughly freed from balsam, carefully brush it with a camel's-hair brush, and mount in Canada balsam in the ordinary manner.

5. Observe the arrangement of the plates and spines in different regions of the body wall. Along the middle of the oral surface of each ray may be seen the shriveled remains of the tube feet, or **ambulacra.** The region in which they lie is the **ambulacral area.** The plates along this tract are the **ambulacral plates.** One row of plates on each side of these ambulacral

plates are known as the **interambulacral plates**. Examine these closely for comparison with the sea urchin.

6. The wartlike elevation on the aboral surface is the **madreporic body**. Note that it is situated opposite one of the **interradial angles**. Examine it with a lens.

7. Make drawings of the oral and aboral surfaces of the starfish.

ALCOHOLIC SPECIMEN.

1. Briefly review the points noticed in examining the dried specimen. Bend the rays; their flexibility is now much less than in life.

2. Compare the spines of different areas as to their shape, size, and degree of mobility.

3. Between the spines are soft, tapering projections, the **aboral tentacles**.

4. Observe a circle of projections surrounding the spines; delicately pinch them with the forceps to determine their consistence; remove some of these bodies to strong alcohol; mount temporarily in turpentine on a slide, cover, and examine with a low power. There should be distinguished a short stalk bearing a pair of pinchers; these bodies are the **pedicellariæ**. In the live starfish these pinchers may be seen continually snapping; they are supposed to serve in removing foreign matter from the body.

5. The soft, cylindrical projections along the median tract of the oral surface of each ray are the **ambulacra** or **tube feet**. Remove one of them and examine it with care. Note the arrangement of the series.

6. Press apart the tube feet and find running along the median line of the ambulacral groove, a yellowish or whitish ridge, the **nerve** of the ray. Trace it to the soft membrane bordering the mouth, the **peristome**, and find the **nerve ring** around the mouth.

7. Trace the nerves also to their outer ends and find a reddish or yellowish elevation, the **eye-spot**, borne at the base of a median terminal **tentacle**, resembling a tube foot.

8. The eye-spot is borne on a distinct, but minute, plate. Compare young and old specimens to see that whatever the size, this single ocular plate with its eye-spot is always at the end of the ray. Count the ambulacral plates in a short and in a long ray. Where do the new plates develop?

DISSECTION OF THE STARFISH (IN WATER).

1. The ray opposite the madreporic body is the **anterior ray.** Cut into its aboral wall near the outer end, and from this point cut along the upper part of each side of the ray, an inch or two toward the disk; raise the flap thus freed, and, avoiding internal organs, continue the cut on each side to the disk.

2. Attached to the aboral wall find a pair of elongated, branched bodies, the digestive glands, or **ceca.** Note how each cecum is held in place by the thin **mesentery.**

3. Along the middle line of the aboral wall, inside, is a yellowish streak, the **extensor muscle** of the ray; with forceps prove its general structure.

4. Along each side of the ridge in the floor of the ray, observe rows of thin-walled sacs, sometimes distended, but more often collapsed in alcoholic specimens. These are the **ampullæ,** or **ambulacral vesicles.** Watch the ampullæ while pressing on the tube feet, and *vice versa.* If a specimen injected with coloring matter be at hand, it should now be examined.

5. Near the base of the ray find, on each side, an elongated body resembling a bunch of grapes, and of a lighter color than the ceca; these are the ovaries and spermaries, and are very much alike in appearance in the two sexes, and only distinguishable by color (the spermaries being lighter colored), or by microscopic examination in the living specimens. Find the point of attachment of one of them. The openings in the interradial angle are not very evident.

6. Cut along the sides of the two rays lying on the right and left of the anterior ray, connect the cuts at the interradial angles, and turn back the cover of the three rays and disk. Within the

disk is the large, thin-walled stomach. Examine this organ carefully. Pass a blunt probe into the mouth and explore its interior.

7. Observe the large lobes of the stomach extending a short distance into the rays; lift one of these lobes and trace the thin **retractor muscles** of the stomach to the sides of the ridge in the ray.

In the live starfish the stomach is often found protruded and surrounding a mussel or an oyster; after digesting and absorbing its soft parts the stomach is retracted.

8. Turning to the ceca of the anterior ray, trace them toward the stomach; find the union of their tubes and the entrance of their common duct into the stomach. Observe the place where this tube enters the stomach, in reference to the corresponding lobe of the latter.

Carefully cut the mesentery along the aboral wall and wholly free the ceca of this ray from all attachment above. Note that the mesentery is double.

9. Hold the starfish inverted and pour water through the mouth into the stomach to show its shape.

10. In the other two rays which have been opened, cut across the common ducts of the ceca close to the stomach, and leave them attached to the aboral walls.

11. Find the extremely short intestine connecting the stomach with the upper wall of the disk, near the junction of the extensor muscles of the rays. Find, also, some small branched appendages of the intestine. The anal opening is minute.

12. Sever the intestine close to the aboral wall, cut across the disk close to the madreporic body, and remove entirely the roof of the disk and the three rays.

Make a drawing of the organs now exposed, showing the ceca in one ray, the reproductive bodies in another, and the ampullæ in the third.

13. Thoroughly examine the stomach, and remove it after cutting across the short esophagus.

14. The S-shaped **stone canal** may now be seen passing downward from beneath the madreporic body.

15. Traced to its lower end, the stone canal may be found to enter a membranous hollow ring, whose outer border rests against the inner surface of the hard parts surrounding the mouth; this tube is the **circumoral water ring**. Connected with its inner surface, find several pairs of pouches, which in the contracted state are mere buttonlike projections. How many of these are there, and are they all in pairs?

Observe also the pouches, like ampullæ, connected with the upper part of the hard ring around the mouth. Press on the water ring at the level of the peristome, and watch the effect of this action on these last-named pouches or vesicles. Is there any connection between them and the water ring?

16. Inclosing the stone canal is a thin membrane, the **pericardium**. Carefully tear it away. Alongside the stone canal is a soft tube, sometimes called the "**heart**," but whose function is doubtful.

17. Cut across the middle of a ray in two places, about an inch apart, and make a careful study of the part included between the cuts. Remove the hepatic ceca, observing again how they are suspended by the mesenteries. Cut into the aboral wall in the middle line and spread open the ring. Observe the depressions in its inner surface; in the bottoms of these depressions find small holes. What is the relation between these holes and the nearest structures seen on the outside?

18. Slowly peel away the thin membrane which lines the interior of the ray, noting especially the connection between this membrane and the depressions above noticed. Also watch closely the aboral tentacles while tearing away this lining membrane.

19. Turn now to the outside of the ray and gently scrape the surface. A thin layer here may also be easily removed. Thoroughly clean a small area, noting that the aboral tentacles come away with this layer.

There will now remain a tough white layer in which are embedded the calcareous plates which constitute the **skeleton**.

Bend this membrane to see the relations of the calcareous plates to the membrane and to each other.

20. By picking with the forceps prove that the membrane is continuous over both the inner and outer surfaces of the plates, as well as between them. This is an important point, as the calcareous plates are developed in and by the membrane.

Part of the membrane, if not all, has the power of contracting, by means of which motion is effected. Note the perforations in the membrane in its thinner portions between the plates where the aboral tentacles passed out.

21. Reviewing what was noticed in the examination of the inner and outer membranes, it will be evident that the aboral tentacles are tubular extensions of the body formed by the protrusion of the inner membrane through the middle membrane, these tubes being covered by the outer membrane.

22. Turn now to the tube feet and their ampullæ and make out their relations to each other and to the adjacent parts of the skeleton. The calcareous plates which form the sides of the ambulacral groove are the ambulacral plates.

23. Pick away a few of the ampullæ and then the corresponding tube feet, comparing the arrangement of the two. In this way clean the ambulacral plates and examine them carefully.

24. Alternately press the ambulacral plates of the two sides together and separate them to see the range of motion allowed by the joint. Observe the muscles connecting the ambulacral plates of the opposite sides, just inside of the nerve.

25. In the angle formed by the ambulacral plates, find the cut-off end of the **water tube** of the ray. Insert in the end of this the point of a drawn-out glass tube, and inflate. When the ampullæ are distended, press on them with the finger and note the effect on the tube feet; with a lens examine the distended ampullæ. In fresh specimens the ampullæ may be injected with a colored liquid or with gelatine to be kept as permanent preparations. In such preparations and in a microscopic section

of a properly prepared ray, it may be seen that the water tube of the ray sends off side branches to the tube feet, and also that the cavities of the tube feet and ampullæ are continuous. By the contraction of the ampullæ the tube feet are extended, and by the muscles in their walls they are moved from side to side and applied to the surfaces on which the starfish rests. The end is fixed by means of the suckerlike disk at the tip of the foot to some foreign object; then, by the contraction of the tube feet, the starfish pulls its body along.

The water finds its way through the madreporic body into the stone canal, thence to the water ring around the mouth, and from this to the radial canals. The water thus taken in probably serves for respiration as well as for locomotion.

26. Make a drawing of a cross section of a ray, showing as many as possible of the above-noted points of structure. A slide with a series of very small starfishes shows well how the rays are formed as outgrowths of the disk.

Read *Seaside Studies in Natural History*, Agassiz.

Topics for Reports. — Starfishes and the Oyster Industry.

THE SEA URCHIN.

Study of a Live Sea Urchin.

At low tide search the tide pools for sea urchins. For collection and study, follow the directions given for the study of the live starfish. Keep sea urchins in a salt-water aquarium and study their habits. Turn a sea urchin upside down in the aquarium. Can it turn back? How does it accomplish this, and how long does it take to right itself?

The requisites for this work are, cleaned skeletons, or tests, alcoholic specimens, microscopic sections, etc., as in the case of the starfish.

The Cleaned Test.

1. Observe the radial distribution of the parts around an axis, at one pole of which, the *oral pole*, is a large opening. At the

opposite pole, the *aboral pole*, is a circular area composed of several small plates, near the center of which is the anal opening.

2. Note that the test is composed of distinct pieces or **plates**. Put one of the plates into a little dilute acid and note what occurs.

3. To make out the real nature of the skeleton, proceed thus:—

a. Handle an entire decalcified specimen, *i.e.* one from which the calcareous matter has been removed by chromic or other acid. Observe that the body walls and spines are still present.

b. Examine a microscopic section of the decalcified body wall to see that there was soft living matter, both on the outside and on the inside of the calcareous plates.

c. Grind down and mount a thin section of a plate, as in the case of the starfish, and see that not only is the plate wholly inclosed in the body wall, but that it forms a network whose meshes were penetrated by the soft living substance of that body wall. It should now be clear that the plates were formed by the deposition of calcareous matter within the living tissues of the body wall. The joints, or sutures, between the plates are formed by the absence of the deposit of calcareous matter.

4. Returning to the entire test, study the arrangement of the plates, their variations in shape, size, etc. Into how many similar areas may the surface of the test be divided? To make out these points, and the shapes of the plates, pull apart a piece of a dried test that was left over from previous dissection.

5. At the aboral pole, observe a small, distinctly marked-off area, including numerous small plates. This is the **anal area**, and the plates are the **anal plates**. Unlike the other plates, these, in the living sea urchin, are movable. They surround the **anus**.

6. Surrounding the anal area are the five large **genital plates**, each having a **genital opening** near its outer angle.

7. With a lens examine the largest of the genital plates; its perforated portion serves as a **madreporic body**.

8. Radiating from the apex of each genital plate is the zigzag **interradial suture**. How many kinds of plates are found within the area included by two adjacent interradial sutures? The perforated plates are the **ambulacral plates**, and the unperforated, the **interambulacral plates**. Compare these two sets of plates with the corresponding parts of a starfisn.

9. The ambulacral plates form the **ambulacral areas**. Trace each of the ambulacral areas to its aboral end, and find at its apex a small plate wedged in between two adjacent genital plates. These smaller ones are the **ocular plates**. Note the small opening from which projects an unpaired tentacle, the end of the radial water tube.

10. Carefully compare the hard parts of the starfish and sea urchin. Wherein are they alike, and wherein do they differ? What changes in growth would be necessary to convert one of these forms into the other? What part of a starfish is homologous with the anal area of a sea urchin?

11. Make careful drawings of the oral surface, of the aboral surface, and of the side of the test.

Alcoholic Specimen.

For the sake of review and comparison, it is well to have the cleaned test before you during this study.

1. Observe the soft membrane, the **peristome**, on the **oral surface** and the **teeth** projecting from the **mouth**.

2. At the aboral pole look for the anus and genital plates.

3. Examine one of the largest spines; move it about to see its range of motion. Remove it and make out how it is articulated to the test. The fleshy tube ensheathing the base is muscular tissue, by the shortening of which the spine is moved. Clean the spine and make a drawing of it.

4. Note any variations in the size and shape of the spines in various regions.

5. Study carefully the arrangement of the spines, using the cleaned test for comparison.

6. Between the spines in certain areas find soft tubular projections, the **tube feet**, or ambulacra. In life they may be extended a considerable distance beyond the spines, being used for locomotion, as in the starfish; carefully examine the tips of the tube feet to find what is therein contained.

7. Find also among the spines and on the peristome, slender, flexible stalks, bearing three-pronged pinchers. In life these pinchers keep opening and shutting.

8. Pick away the spines and other projections preparatory to dissection.

Dissection of the Sea Urchin.

After removing the spines, cut, or better, saw with the blade of a metal saw, through the equator of the test; place under water and carefully raise the aboral portion at one side.

1. Press on the tips of the teeth to show their connection with the complicated apparatus known as the **lantern**; now open the test till the two halves are side by side and complete the dissection under water.

2. Arising from the middle of the inner surface of the lantern find the brown **esophagus**. Trace this as it passes in festoons about the body walls, widening to become the stomach. Trace the intestine to the anus, describing carefully its course.

3. Pick away the digestive tube from the oral half of the test. Note the five double rows of ampullæ; between each of these double rows runs the radial water tube, and between the water tube and the test is the radial nerve.

4. In the aboral half, note the ovaries and spermaries in the loops of the intestine. Trace their ducts to the genital pores.

5. After cleaning away the intestine, ovaries, and spermaries, trace the ampullæ as they converge to the ocular plate. Compare the inside and outside of the test to see if the ampullæ are really opposite the ambulacral pores noticed in the dry test.

6. Study the lantern, make out how it is supported, and how its various parts are moved, and how they are used.

Place in water the pieces of test left after dissection and macerate till the spines are readily detached. Then clean and keep them for the next class. They will be useful for pulling to pieces to make out the structure of the test.

Topics for Reports. — Boring Sea Urchins.

CHAPTER XIX.

TROCHELMINTHES.

THE WHEEL ANIMALCULE (ROTIFER).

ROTIFERS are often found in the water of an aquarium wh
clams and crayfish have been kept; pick out clusters of pl
growth, found in the rubbish and sediment in the aquarium,
on the shells of clams; with a lens look at the walls of t
aquarium for small, white, wormlike forms.

The body of the wheel animalcule is tapering, ending in a tw
forked **foot**. At the larger end, when expanded, are two circul
disks, fringed with **cilia**; the disks are retractile, as in Vorticell
Between the disks is the mouth; this opens into the **pharynx**
lined with teeth; back of the pharynx are the stomach an
intestine.

Rotifers are classed with the worms; though small, the pres
ence of a distinct digestive tube, a distinct nervous system, and
organs of sight and hearing, show the Rotifer to be much more
highly developed than the protozoans.

Rotifers have been dried and kept for years, and yet when put
into water they revived.

Study carefully:—

1. The mode of locomotion.
2. The action of the disks and cilia.
3. The motions of the pharynx.
4. The contraction and expansion of the body as a whole.

Make drawings showing the body both in the expanded and in the contracted state.

Read the "General Characters of Rotifers" in Packard's *Zoölogy;* "Rotifera" in Claus and Sedgwick's *Text-book of Zoölogy;* "Trochelminthes" in Parker and Haswell's *Text-book of Zoölogy.*

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